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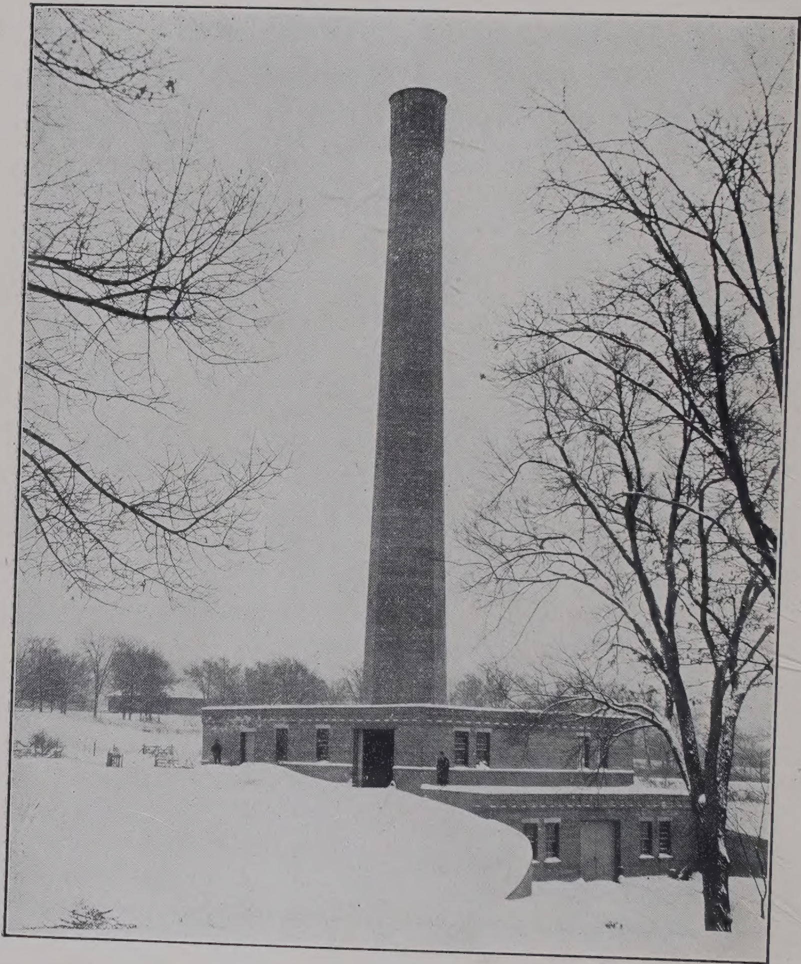

Crematory built by The Municipal Engineering Company at Fort Leavenworth, Kans.

Frontispiece.

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GARBAGE CREMATORIES IN AMERICA

BY

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TO MY FATHER

PREFACE.

UNTIL May 1904 the writer had not directed his attention to the construction of garbage crematories, although he had been deeply interested in kindred problems. It then unexpectedly devolved upon him to remedy defects in the design of garbage crematories already built, and to advise regarding the prosecution of patents in which friends were interested.

This work involved investigation of what has been done in the field of crematory construction—a study which has been carried on by two methods, namely, inspection of installations actually built, and analysis of features of design as discoverable from Patent Office records.

To place the useful data so secured where others may profit by them is one object of this book. An attempt has been made to indicate the principles of design of every type of crematory built in the United States, and to give a list of installations at least large enough to enable any interested party to look into the merits and to mark the development of any system. The writer would be glad to receive supplementary data.

However, the scope of the book is not limited to a discussion of designs. It extends to a discussion of matters that

must be considered in connection with the selection of a system of garbage or refuse disposal, as well as to those matters that bear upon the selection of a crematory to meet any particular requirements.

WM. MAYO VENABLE.

NEW YORK, April 13, 1906.

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CHAPTER I.

THE PROBLEM OF DISPOSING OF WASTE MATERIALS.

THE reasons why the problem of refuse disposal is receiving an ever-increasing amount of attention from engineers, municipal authorities, and from the American public do not lie in the newness of the problem, but rather in an intellectual and æsthetic awakening of the people. The same spirit that leads men to realize the corruption of politics and business, and to attempt to remedy these conditions by adopting new methods of administration and new laws, also leads to a realization of the primitiveness of the methods of waste disposal still employed by most communities, and to a consequent desire for improvement.

This spirit is more than normally manifested now in the treatment of all matters affecting public health, especially matters connected with the spread of diseases known to be infectious or contagious. The sdtuy of bacteriology has been effective in stimulating a realization of the advantages of systematic destruction of polluted materials. At the same time there has developed a general public desire to prevent the destruction of the beauty of Nature in the outskirts of our cities and towns by neglect or abuse. A witness of this

is the rapid spread of the park system, and the enthusiasm with which the people greet systematic and effectual efforts to remove blemishes from the face of Nature in their respective towns.

Yet the crudity of the methods of refuse disposal in most of our American cities is almost incredible to an intelligent person when his attention is first directed to observe such matters, the disposal of garbage being in many cities less intelligently managed than among savages, and the disposal of litter, tin cans, waste paper, etc., a class of waste with which savages do not have to deal, being conducted in so slovenly a manner as to excite disgust in any person who realizes the facts.

The first discovery of the fact that practically all of the towns on the rivers of the great Mississippi River system not only turn all of their liquid sewage into the streams unpurified, but also dump into the rivers their solid vegetable garbage and night-soil, barge-loads at a time, is likely to come with considerable shock to the average citizen; but even such abominable practice is little worse than the pollution of the air by the foul odors of a garbage or refuse dump, nor is the pollution of streams probably a greater menace to the public health than the opportunity for insects or dust to carry infection from garbage dumping-grounds. Sanitary and inoffensive disposal of wastes must occupy the minds of municipal authorities in ever-increasing degree until these conditions productive of public nuisance and public danger no longer are tolerated in any community, and until no State will allow any community subject to its jurisdiction to fall into a practice so injurious to the welfare of its neighbors.

It devolves upon municipal governments to remedy these conditions in each municipality, whether the matter be forced upon their consideration by public-spirited officials, local pub-

lic sentiment, or state or federal legislation. Those who are at the head of municipal affairs are often confronted with the necessity of providing an abatement of a nuisance and employing remedies for insanitary conditions before they have become fully conversant with the details of the problem to be solved. Holding office for short terms only, and often being unfamiliar with engineering or sanitary matters, such officers are specially handicapped. In some cases they wisely consult their city engineers, but these officers are often unprepared to report upon the disposal of wastes without first making an extensive investigation, even when they are called upon for advice. In most cases, and in the cases of all small towns, matters of sanitation are left in the hands of the City Council or corresponding body, with help or opposition from the Mayor, health officers if any, Board of Public Works, and Business Men's Club, among all of whom, most frequently, there is not a man prepared by his calling to form a just opinion as to what is necessary.

These City Councils seldom seek preliminary advice upon the subject of garbage disposal, usually feeling it incumbent upon them to handle the matter without putting the city to any expense for such preliminaries. They therefore get in touch with some builder or builders of such apparatus as they think, from a cursory investigation or inquiry, is likely to meet their requirements. Such consultation usually results in the preparing of an advertisement or specification under which bids are taken for "a system of garbage disposal," and the specification is usually drawn in the interests of the particular builder consulted, while the advertisement is too often a perfunctory compliance with the law, not placed so as to give wide publicity to the enterprise.

Such a proceeding does not necessarily imply any corrupt

motives or acts on the part of those engaged in it, but it offers opportunities for improper influences to be exerted, and often defeats the object which should be the principal one—to secure the best plant to meet the actual conditions for the particular community in question. There seems to be no effectual remedy except to secure a broader knowledge, on the part of the prospective purchasers and their representatives, of the conditions to be met, and of the available means of meeting them; and in the last-named category should be included knowledge of what types of structure are controlled by patents and what are free, in order that specifications may admit competition.

Although this book will deal chiefly with cremation or incineration of wastes, and will not pretend to deal with all the methods of disposal that have been proposed or tried, some reference to other methods is necessary in order that the field to be filled by the crematory, that other methods of disposal do not fill, may be completely understood; and in order that the purposes of the other methods may be understood and their value judged, it is necessary to treat briefly of the value of products contained in or recoverable from domestic wastes of various kinds.

Domestic refuse of all sorts consists of what people discard and desire removed from their homes, without expectation of receiving payment in return—in fact, the material which citizens must have removed at some cost, direct or indirect, to themselves or to the community. Obviously such refuse—valueless to the individual—can have but little if any value to the community or to any corporation undertaking to dispose of it; and any value that it does possess depends upon its being susceptible to treatment on a large scale, at comparatively small cost.

The small value that it may possess may be due to discarding of articles of some market value, though valueless to the possessor, which may be recovered by sorting and be sold to other parties; or it may be due to the value of materials contained in the refuse that may be treated chemically so as to recover them in useful form.

The materials in domestic waste that may sometimes be used or converted into marketable products are chiefly these:

1. Kitchen garbage suitable for feeding hogs.
2. Grease and oils in garbage, valuable, when extracted, for making soap.
3. Organic or nitrogenous materials, of use as fertilizers.
4. Materials useful for fuel.
5. Rags and paper.
6. Unbroken bottles.
7. Tin and solder, recoverable from tin cans.
8. Broken crockery, useful for making roads or in building operations.
9. Material suitable for filling.

The recovery of them is usually unsanitary and expensive, and often impracticable. Such recovery at best can only be made to assist in defraying the expense of collection and disposal; and in attempting to recover a part of the valuable products great care must be exercised to insure that the means adopted will in reality extract the value without necessitating an expenditure exceeding that value.

Where all kinds of domestic wastes, including garbage, are thrown into one receptacle, any attempt at sorting as a preliminary part of utilization must be abandoned on sanitary grounds. The only value such refuse may possess is to be found in using it for filling or for fuel. To use it for filling is unsanitary, and its value for fuel is not sufficient to make

it pay in competition with coal, except in rare instances where coal is very expensive. The only sanitary method of disposing of such mixed garbage and refuse is to burn it, obtaining what heat value is practicable, and to use the ashes for filling. Such ashes do not have any considerable value as fertilizer, and they contain a large portion of clinker, fused glass, and porcelain, and cans with the tin burned off.

Garbage is suitable for feeding to hogs only when carefully collected every day, and unmixed with other refuse. Feeding stale or unsterilized garbage to hogs is said to be likely to produce hog-cholera. Therefore this method of utilization is of very limited application, and should be permitted in towns only under the most careful regulation, if at all. In cities it should be prohibited for sanitary reasons, it being impracticable to collect the garbage in suitable condition.

Grease, oils, and fertilizers are extracted from garbage by several "reduction" systems. The garbage is separated by the use of heat and machinery into grease and oil, which always have a market value, water, which is laden with organic matter, and must be disposed of, and "tankage" or the solid pulp, or residue after both grease and water have been removed, which has some value as fertilizer in some localities where there is a market for it near at hand. A complete sanitary disposal must purify the water before discharging it from the works, and this is rarely done.

When the refuse is collected separately from the garbage, the former may be sorted with only moderately unsanitary conditions, especially if it is not mixed with household ashes, and from it may be picked the marketable rags, paper, bottles, and cans for further treatment, the residue going to a furnace for destruction, and the resultant ashes being carted away

or used for filling. The value of these articles sorted out is sometimes considerable, but it is by no means always great enough to pay for the labor of sorting. Whether the process is likely to pay depends upon the source of the refuse, the amount to be handled, and the market for the products. Unless the installation be of considerable size it will not pay the expenses of operation and superintendence; and the burning of the wastes without sorting will be found to be more economical in the end.

The value of any fuel depends upon its concentration—freedom from ashes and water—so that it may be burnt at as high temperature as possible. Refuse consisting principally of paper, household sweepings, etc., free from ashes and moisture, has fuel value superior to wood; but if wet it is not so valuable; and if mixed with ashes it is still less valuable.

In conclusion, therefore, we have to accept the following propositions:

1. The value that can be recovered from domestic refuse in towns and cities never equals the cost of collection and disposal. It may in some cases be made to assist in defraying these expenses, where the quantities of waste to be disposed of are large.

2. The value of the recoverable materials can only be saved where separate systems of collection of garbage and refuse are adopted.

3. The value of refuse for fuel is greatest when garbage, refuse, and ashes are all collected separately.

In each special case whether it will pay, under capable management, to attempt the recovery of any materials in the wastes or the development of power will be found to depend upon local conditions, chiefly upon the quantity to be handled, the price of hauling, the market for the products, the price

of power, and the ability to enforce a separate collection of garbage, wastes, and ashes.

The first thing to be determined by a town taking up the disposal problem is this: *How much garbage, how much night-soil, how much ashes, and how much miscellaneous litter* (paper, house-sweepings, packing-boxes, etc.) *is to be destroyed?* This should be determined *in tons* by actual weight for a definite period, on the city scales. To guess at it is almost worse than not to specify at all. The cost of disposal depends to a very large extent upon the character of material to be destroyed, and it may be three times as much per ton for garbage as for miscellaneous trash. The next problem to determine is whether there will be separate collection of kitchen garbage. If such is to be the case, the method of disposing of kitchen garbage may be determined. This may be by reduction or by cremation.

A reduction process is one by which the vegetable oils are extracted from the garbage. To be perfectly sanitary it must include also the disposal by purification (not sterilization only) of the liquid remaining, and the sanitary disposal of the pulp, or solid residue, for which a value as a fertilizer is usually claimed. The process is foreign to the principal subject of this paper; but it may be noted that the cost of an equipment to carry out reduction completely is several times as great as the cost of a crematory to dispose of the garbage by fire; that difficulties attendant upon making the plant odorless are much greater than for crematories, and that the cost of operation is much greater, while the profits to be realized are problematic, depending upon a very efficient business and technical administration. To make such a plant pay a return on the investment required to build it, it is necessary in most cases for the city to pay a subsidy to assist the operation; in almost

every case the liquid from the garbage, after the oil is extracted, is allowed to enter some stream where it subsequently becomes food for germs of decomposition and injures the water for all purposes.

In a paper* entitled "Disposal of Municipal Refuse" Mr. Rudolph Hering says:

"The Merz process was the first in successful use and is still used in St. Louis. It is briefly described as follows: The garbage is dumped into a hopper from which the superfluous water drains off. It is then spread out and as much foreign matter as possible, such as cans, bottles, rags, metal, and bones, is picked out and sold. Then it is dumped into hot-air driers and stirred with mechanical mixers for about six hours, when it becomes comminuted, and is dark brown and greasy. In this condition it is put into extractors or closed tanks into which naphtha is made to percolate for the purpose of dissolving and thereby extracting the grease. The grease solution is drawn off, separated from the naphtha, barreled, and sold. The naphtha is vaporized, then condensed and used again. The tankage is ground, sifted, and sold for fertilizing purposes, or has been used in its natural state for fuel."

"The Simonin process is quite similar."

"The Arnold process is used chiefly in New York, Philadelphia, and Boston. It is the simplest, and apparently the most successful and least costly. The garbage, after picking out metals, glass, and other undesirable stuff, is dumped into digestors, holding each about eight tons. In them the garbage is cooked several hours under pressure of live steam. It is then allowed to fall through a valve at the bottom of a continuously rolling press which separates the fluid from the tankage. The fluid consists of grease and water which are

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* Transactions, Am. Soc. C.E. Vol. LIV, Part E, pages 263 to 308.

subsequently separated by gravity, the water flowing off into a sewer and the grease into tanks to be barreled and sold. The remaining solid matter or tankage is dried and then either ground and sold as a filler for fertilizers, burned, or wasted."

Mr. Hering gives the following table of costs of reduction:

COST OF REDUCTION.

City.	Process.	Date.	Cost to City per Ton.	Authority
St. Louis	Merz	1897	$1.80	Chapin
Buffalo	Merz	1900	0.69	Chapin
Buffalo	Merz	1903	0.77	•Local
Providence	Simonin	1898	1.62	Chapin
N. Y. City (Borough of Manhattan)	Arnold	1899	0.60	Chapin
N. Y. City (Borough of Manhattan)	Arnold	1903	1.71	Local
Boston	Arnold	1904	0.96	Local

Another process separates the grease and water from the tankage by distillation, and subsequently separates the grease from the water. Processes are also proposed to produce alcohol for use in the arts by fermentation and distillation of garbage.

In any given case, unless the sale of the product of reduction produces an income sufficient to pay all the costs of operation and interest and depreciation on the plant, the process cannot be conducted without a subsidy. This subsidy should never exceed the cost of disposal by other means. Any reduction plant produces tankage or fertilizer that has a most offensive odor, even if the process be so conducted as to be inoffensive, Tankage should never be transported through a residence or a business district. Therefore, there are few places where reduction can be adopted to advantage, compared with the number of places where some disposal system must be applied.

The next problem to be considered, and the one that is too often neglected until after contracts for building are let,

is the location of the disposal plant. This should be determined by the conditions of haul. If garbage, ashes, and refuse are all collected separately, the best *American practice* is to *haul the ashes* direct to the dump for filling, and to haul the other wastes to the disposal plant, though collecting them in separate wagons. British practice differs from this in that the ashes are usually passed through the crematory with other wastes. The merits of these two methods will be discussed later.

If reduction is resorted to, or if garbage is to be dumped at sea, as is often done, there remains only the miscellaneous waste to be destroyed. This is sometimes picked over and sorted, all materials of salable value being placed together, baled and sold, and the residue burned in a refuse-furnace, with the production of some steam for power purposes, but in most cases the refuse is not sorted, but burned for the sole purpose of destroying it.

A furnace that may be admirably suited for burning refuse to produce power may be worthless for burning kitchen garbage, and *vice versa*, but furnaces may be designed to burn both. In most of the small cities and towns in the United States the conditions are such that the crematory should be capable of burning *either kitchen garbage, or miscellaneous refuse, or both* at an economical cost and without producing a nuisance. But it is especially important that the *quantities of each shall be known* before the contract is let, and not merely the total quantity of all combined.

Assuming that it has been determined what material is to be burned, the crematory should be located so as to reduce the haul to a minimum, in order that the cost of collection may be kept within the proper bounds. It must be remembered that *ashes will have to be hauled from the crematory,* as

well as garbage to it. The crematory should preferably be located at the center of the collection district or at the ash-dump, if the latter is not at too great a distance. The location will determine to some extent the kind of building that should be erected to be in keeping with surrounding objects.

The preliminaries being determined, it remains for the authorities to determine upon a plant, or at least upon the conditions that they will require prospective bidders to fulfill. To throw some light upon what should be exacted and expected, so that those called upon to fix such requirements may not be acting wholly in the dark, the writer offers the review of the present status of the art, hoping that it will be found of use. He is aware that connection with a company actively engaged in building crematories may be regarded by some as disqualifying him from presenting these matters with candor, and therefore acknowledges such connection, that readers, thus forewarned, may judge whether or not the following statements are the result of a narrow-spirited promotion of selfinterest.

In the foregoing the disposal of street-sweepings has not been regarded, but in the following chapter some reference to their quantity and character will be found.

FIG. 1.—Receiving-floor of a Large Dixon Crematory.

CHAPTER II.

QUANTITIES OF VARIOUS WASTE MATERIALS AND SYSTEMS OF COLLECTION.

The domestic wastes to be collected and disposed of by a municipality or an institution that must dispose of its own wastes are of four kinds, namely, night-soil, garbage, refuse, and ashes. The municipal collection system must also provide for removing and disposing of street-sweepings.

Of these wastes the first is the most difficult and the most expensive to dispose of; but it is usually discharged into sewers, and its final reduction is to be accomplished in the sewage purification plant. Its collection by other means, wherever done, requires the use of air-tight receptacles for its transportation. Under no circumstances is it collected with other waste materials.

The other three classes of domestic wastes may be collected separately or together, and actually are collected separately in some places and together in others, there being little uniformity in this practice in American cities.

In selecting on a collection system there are three matters to be considered: the sanitary aspects of the collection system, the cost, and the method of disposal. We should consider these in determining both the collection and the disposal of these wastes.

From a sanitary point of view the garbage should be collected as often as possible, especially during the summer, as it rapidly ferments and becomes offensive. The collection

should be daily, if the amounts justify it, and under no circstances should it be less frequent than twice a week. On the other hand, if ashes are kept unpolluted by garbage, there is no sanitary reason why they need be collected any more frequently than is most convenient for the collecting system; and miscellaneous dry refuse, such as waste paper, rags, packing-house sweepings, etc., may also be allowed to accumulate in suitable receptacles until the quantity is convenient to remove. Obviously, from a sanitary standpoint, the garbage should be collected separately and frequently, while the refuse may be collected either alone or mixed with the ashes, as may be found best when the disposition is determined upon.

We now come to consider the relative cost of separate and common collection systems.

Kitchen garbage, containing no paper or other litter, weighs between 60 and 90 lbs. per cubic foot, according to what composes it and the amount of water contained. It is heavier than the other wastes. It requires water-tight carts for its proper transportation, and the carts should be covered at all times except when the garbage is being put into them. Obviously, a separate collection system for it will be the least expensive if the work is done with any regard to sanitary or æsthetic principles. The miscellaneous wastes will weigh from 7 to 10 lbs. per cubic foot, and the ashes from 70 to 100 lbs. per cubic foot. A team that could haul 1 cubic yard of ashes up the prevailing grades could haul some seven yards of trash. If the collection is separate, large wagons can haul the trash, and moderate-sized ones the ashes. The wagons can be made of the best size for the purpose; while with medium-sized wagons or carts the loads will vary exceedingly, being subject to the judgment of the drivers. As the frequency of

the call of the wagon can be made to suit the convenience of the collection system adopted, there is no gain by having one wagon collect two kinds of wastes; hence separate collection is the cheapest where properly administrated.

Let us now consider the method of disposal in this connection.

If the different wastes are disposed of by different processes, the separate collection system is necessary; if not, it cannot prove an inconvenience. If all products are to be cremated, if separately collected they can be introduced into the furnace on grates especially adopted for their proper burning. If the refuse is to be sorted, it can be handled better if unmixed with cinders or decaying vegetables; and if the cinders are to be burned as fuel, they may first be screened to remove the completely burned ash. There appears, then, no reason for adopting a common collection system except one, which we will now consider, while every consideration of sanitation and economy dictates three separate collection systems.

The argument in favor of a single collection system is that the people cannot be persuaded or forced to keep the garbage, the ashes, and the wastes separate in the cans. In small communities where a considerable portion of the population is of a low order of intelligence this is a real difficulty; but in such communities the separate collection system is not usually so essential. In large cities the regulations can be enforced easily if seriously undertaken, and this argument is a confession of executive indolence or of failure to grasp the situation.

Whether the collection is to be made by the city or by private contract is a question of policy upon which practice differs. The objection to a municipal collection is based upon the usual charge of dishonesty or incapacity in administration by public officials. But it should be remembered that it is as easy to be dishonest or neglectful in awarding contracts to

others as in supervising work. One disadvantage of the contract system lies in the inability of the contractor to force citizens to keep the refuse in proper receptacles; and another is that the contractor is tempted to make his visits as rare as possible, to keep his expenses down. No system can insure honesty where people allow dishonest men to represent them; and no system can insure efficiency where the incapable or the lazy are in the executive positions.

Accurate data regarding the quantities of wastes of various kinds to be disposed of in any city is very difficult to procure. The best compilation of information on this subject for Americans is contained in Mr. Rudolph Hering's paper, referred to in Chapter I. From that paper the following tables that bear numbers are taken. The unnumbered tables

TABLE I.

AVERAGE PERCENTAGE COMPOSITION OF GARBAGE.

Component Parts.	United States.	England.	Berlin.
Moisture	70%	65%	60%
Grease	3	2	2
Animal and vegetable	20	24	30
Rubbish	7	9	8
	100	100	100

TABLE II.

AVERAGE PERCENTAGE COMPOSITION OF STREET-SWEEPINGS.

Component Parts.	New York. (Craven.)	Washington. (Wiley.)	Berlin. (Vogel.)	London. (Letheby.)
Moisture	37	35	39	35
Organic matter	31	20	23	36
Ash	32	45	38	29
	100	100	100	100
Proportion of organic matter to ash	1:1	1:2.2	1:1.6	1:0.8

are taken from Mr. Goodrich's book, "Disposal of Towns' Refuse." *

"From an inquiry made by the United States Department of Agriculture in 1898 among the cities of the United States, it was found that the average quantity of street-sweepings collected annually per 1000 persons was 168.9 tons.

"The quantity of sweepings reported for London is about 150 tons, and for Berlin about 125 tons annually per 1000 persons."

TABLE III.

PERCENTAGE COMPOSITION OF RUBBISH.

Kind of Material.	New York. (Craven.)	London. (Russell.)	Berlin. (Bohm & Grohn.)
Paper	75.0	39.4	23.3
Rags	15.5	3.6	6.3
Rubber	0.1	.....	.....
Leather	1.8	.....	3.8
Straw	.....	29.7	19.7
Wood	1.4	.....	2.2
Metals	3.3	9.2	4.2
Glass	2.9	13.1	7.0
Stoneware	.....	5.0	33.5
	100.0	100.0	100.0

TABLE IV.

PERCENTAGE COMPOSITION OF CITY REFUSE.

Component Parts.	New York. (Craven.)	Boston. (O'Shea.)	Washington. (Sutcliffe.)	London. (Codrington.)	Berlin. (Bohm & Grohn.)
Ashes	66	70	28	48	31
Garbage	10	18	20	9	19
Street sweepings	18	9	45	40	41
Rubbish	6	3	7	3	9
	100	100	100	100	100

* In his tables, Mr. Hering gives credit to those whose reports are used in these compilations.

TABLE V.

PERCENTAGE COMPOSITION IN WEIGHT OF CITY WASTES, EXCLUDING STREET-SWEEPINGS.

Cities.	Ashes.	Garbage.	Rubbish.	Authority.
New York	81	12	7	Craven
Boston	76	20	4	O'Shea
Washington	51	36	13	Stutler
Trenton	75	21	4	Hering
Montreal (summer)	10	65	25	Pelletier
" (winter)	60	25	15	"
London	82	14	4	Codrington
Berlin	53	32	15	Bohm & Grohn

In Colonel Codrington's report to the Local Government Board in 1888 he gave the following analysis of London refuse:

	Per Cent.
Ashes	52.6
Breeze (cinders)	28.8
Soft core (animal and vegetable refuse)	14.2
Hard core (broken pottery, etc.)	2.9
Coal	0.15
Bones	0.25
Rags	0.425
Old iron	0.35
Old metals	0.025
White glass	0.075
Black glass	0.225
	100.000

AVERAGE COMPOSITION OF ASH-BIN REFUSE. (HUTTON.)

	Percentage of Weight.
Breeze and cinder	50.0
Paper, straw, fibrous material, and vegetable refuse	30.0
Coal	0.7
Bones and offal	0.6
Rags	0.4
Coke	0.3
Ash	12.0
Dust and Dirt	20.0
Bottles, 1%; tins, .7%; metals, .2%; crockery, .6%; broken glass, .5%: a total of	3.0
	100.0

Mr. Hering arranged these and the table given on page 21 for comparison as follows:

TABLE VI.

AVERAGE PERCENTAGE COMPOSITION OF ENGLISH REFUSE. (CLASSIFIED APPROXIMATELY.)

Component Parts.	Average English. (Hutton.)	London. (Russell.)	London. (Codrington & Weston, 1886.)
Coal	0.7	0.8	0.2
Coke	0.3	.....	.....
Breeze and cinder	50.0	63.7	28.9
Ash	12.0	...	.....
Dust and dirt	20.0	19.5	52.5
Total ashes, etc.	83.0	84.0	81.6
Vegetables	.....	4.6	.....
Paper	13.0	4.3	14.0
Fibrous material	.....	3.2	.....
Bones and offal	0.6	0.5	0.3
Total garbage	13.6	12.6	14.3
Rags	0.4	0.4	0.4
Metal	0.9	1.0	0.4
Glass	0.5	0.45	0.3
Bottles	1.0	1.0	3.0
Crockery	0.6	0.55	.....
Total rubbish	3.4	3.4	4.1
Total refuse	100.0	100.0	100.0

("In America paper and much of the fibrous material is more usually classified under rubbish.")

This shows a very remarkable agreement of the three analyses.

TABLE VII.

PERCENTAGE OF WATER, COMBUSTIBLE MATTER, AND INCOMBUSTIBLE MATTER IN MIXED REFUSE, EXCLUDING STREET-SWEEPINGS.

	New York.			London.			Berlin.		
	Water.	Comb.	Incom.	Water.	Comb.	Incom.	Water.	Comb.	Incom.
Ashes	...	20.3	60.7	...	23.9	58.1	....	1.6	51.6
Garbage	8.4	3.3	0.3	9.0	4.5	0.5	19.2	12.2	0.6
Rubbish	...	6.3	0.7	...	3.6	0.4	....	13.5	1.5
Total	8.4	29.9	61.7	9.0	32.0	59.0	19.2	27.3	53.5

TABLE VIII.

AMOUNT OF REFUSE IN FOUR LARGE AMERICAN CITIES.

Cities.	Author.	Total Refuse per Annum in Tons.	Population Served.	Refuse per 1000 Persons per Annum in Tons.	Refuse per Capita per Annum in Lbs.
New York	Craven	1,699,000	2,049,000	835	1670
Boston	Sullivan	391,000	530,000	740	1480
Washington	Stutler	171,000	300,000	570	1140
Baltimore	Wickes	380,000	509,000	750	1500

TABLE IX.

APPROXIMATE AVERAGE AMOUNTS IN TONS PER ANNUM PER 1000 POPULATION OF VARIOUS CLASSES OF WASTES IN MIXED REFUSE OF NEW YORK, LONDON, AND BERLIN.

Material.	New York. (Craven.)		London. (Codrington and others.)		Berlin. (Bohm & Grohn.)	
	Per Cent.	Tons.	Per Cent.	Tons.	Per Cent.	Tons.
Ashes	66	550	48	192	31	93
Garbage	10	85	9	36	19	57
Street-sweepings	18	150	40	160	41	123
Rubbish	6	50	3	12	9	27
Total	100	825	100	400	100	300

TABLE X.

APPROXIMATE AVERAGE AMOUNTS IN TONS PER ANNUM PER 1000 INHABITANTS OF WATER, COMBUSTIBLE AND INCOMBUSTIBLE MATTER IN THE MIXED REFUSE OF NEW YORK, LONDON, AND BERLIN, EXCLUSIVE OF STREET-SWEEPINGS.

	New York.			London.			Berlin.		
	Water.	Comb.	Incom.	Water.	Comb.	Incom.	Water.	Comb.	Incom.
Ashes	..	138	412	..	56	136	..	3	90
Garbage	58	24	3	22	12	2	33	22	2
Rubbish	..	44	6	..	10	2	..	24	3
Total	58	206	421	22	78	140	33	49	95
	(685 tons.)			(240 tons.)			(177 tons.)		

LONDON ASH-BIN REFUSE.

The following analysis is taken from a paper read by Mr. Jos. Russell before the Sanitary Institute on Feb. 10th, 1892.

Component Parts.	Average per 1000 Loads.				Per cent by Weight.
	Tons.	Cwts.	Qrs.	Lbs.	
Breeze (cinders and ashes)	611	3	0	4	63.69
Fine dust	187	1	0	8	19.51
Vegetable, animal, and various mineral matters	44	3	3	20	4.61
Waste paper	41	1	1	20	4.28
Straw and fibrous material	30	18	1	6	3.22
Bottles (5000)	...	..	.	..	0.96
Coal and coke	8	0	2	14	0.84
Tins	7	11	2	22	0.97
Crockery	5	5	0	0	0.55
Bones	4	12	1	1	0.48
Broken glass	4	11	2	2	0.47
Rags	3	15	3	16	0.39
Iron	2	0	0	20	0.21
					100.00

"The amounts per capita per annum in the United States may be roughly stated to range as follows:

Ashes	300 to 1200 lbs.
Garbage	100 to 180 lbs.
Rubbish	50 to 100 lbs."

There have been a number of attempts to derive valuable fertilizer from the ashes produced by cremating garbage; but these ashes do not, as a rule, contain sufficient value to pay for so using them, at least in most localities.

Col. Morse gave the following analysis of ashes from the Thackeray Incinerator at San Francisco, Cal.:

	Ashes Per Cent.	Clinker Per Cent.
Unconsumed carbonaceous matter	1.82	6.74
Silicon dioxide	51.91	45.54
Iron sulphide	2.73	0.75
Copper sulphide	0.80	trace
Lead sulphide	0.48	trace
Phosphoric acid	0.81	2.52
Aluminum oxide	1.430	12.71
Iron oxide	1.00	1.92
Calcium oxide	15.45	19.59
Magnesium oxide	1.89	1.26
Potassium oxide	0.82	1.46
Sodium oxide	1.73	0.83
Sulphur oxide	1.64	4.10
Carbon dioxide	3.94	2.34
Loss and undetermined	0.62	0.24
Total	100.00	100.00

The American Public Health Association defines the various classes of municipal wastes as follows:

ORGANIC.

Garbage. . . . . The rejected food wastes.
Night-soil. . . . . The contents of vaults and cesspools.
Sewage. . . . . Water-conveyed excreta.
Offal. . . . . The refuse from slaughter-houses and animal substances only.

INORGANIC.

Ashes. . . . . Household, steam, and factory.
Refuse. . . . . Combustible articles from all sources; also glass, iron, crockery, house-sweepings, and generally everything from the house not included in garbage and ashes.
Street-sweepings. . . Compounded of organic and inorganic substances.

The location of the disposal plant has a most important bearing upon the cost of collection. If that plant be located near to the center of the collection district, the haul to it will be shortest. The cost of delivery of garbage or refuse to the disposal plant is made up of the cost of collecting and the cost of hauling after the collecting wagon has been filled. The cost of collecting does not depend upon the location of the disposal plant, but the cost of hauling does.

For instance, assume that collecting and hauling are done with carts that hold a ton, and that the cost of haul and return of cart is 25 cents per mile. If the dump for ashes is two miles distant from the center of the collection district, the cost of hauling to a crematory located at the dump will be 50 cents per ton more than the cost of hauling to a crematory located in the center of the district. As garbage and light refuse produce ashes of less than 10% of the original weight burned, and this ashes must be hauled to the dump, the net saving, by locating the crematory in the center of the district, will be 45 cents per ton.

Where, in large cities, collection districts may be provided with depots at which the various wastes are received, and whence they may be transported by rail or by water to conveniently located incinerating plants, or utilization stations, the advantage of having the destructors placed in the centers of the districts is replaced by the advantage of the depots; and as the cost of such short haul by rail from one part of the city to another is practically independent of the distance, the disposal plant may be large enough to provide for all the wastes, and may be located wherever desired.

CHAPTER III.

THE PROBLEM OF BURNING REFUSE WITHOUT OFFENSE.

To trace the development in this country of the garbage crematory is not as simple a task as might at first appear to one unacquainted with the difficulties of burning garbage and wastes without offense and without undue expense, or to one not conversant with the vast amount of labor that has been put into devising garbage furnaces. Therefore, this presentation will begin with a statement of the conditions to be filled by a furnace in order that it may do the work ideally—conditions not all fulfilled by any practicable furnace, but which we should strive to meet as nearly as possible.

It is well known to all steam engineers that to burn any solid fuel properly there must be a relation between the size of the openings through the grates upon which the burning is conducted and the size and hardness of the lumps of fuel; also that there is a relation between the depth of the fuel on the grate and the economy of combustion; also that there is a relation between the kind of fuel, the depth of fuel on the grate, and the draft required at the grate to secure most complete combustion at the highest temperature. Therefore, when a boiler and grate, with settings, is to be designed to secure the most economical results, it is necessary to know first, the character of the fuel, and the draft available at the grate.

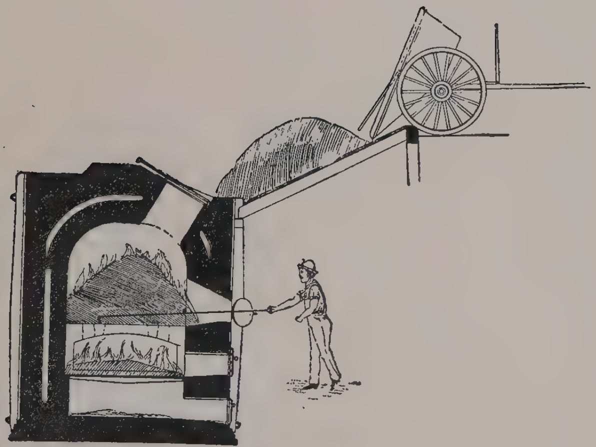

FIG. 2.—Method of operating Crematory. (From an old catalogue.)

If, however, the problem is to burn gaseous fuel or vapor of any character, the problem of securing complete combustion at the highest possible temperature is to admit and to mix with the gas just enough air to secure its thorough combustion, and no more. If less is introduced there is a foul-smelling or smoking vapor ejected from the chimney; if more, the gases are reduced in temperature, and cannot give up as much heat for raising steam in the boilers.

In a crematory we have both of these conditions to be met in an extreme form. Kitchen garbage is not in a condition to burn on a grate at all when first brought to the crematory, unless mixed with a large portion of dry combustible matter, such as cinders or refuse. Therefore, it must usually be given some preliminary drying; while, on the other hand, it contains a large amount of volatile matter which is distilled off by either drying or burning, and will cause the chimney gases to be unspeakably offensive, unless they are heated in the presence of an excess of air to a very high temperature subsequent to their generation.

If the crematory is to burn garbage only, unmixed with combustible refuse or ashes, provision must be made for preliminary drying; but if a mixture is to be burned, the question of whether preliminary drying is necessary, or advisable, depends primarily upon the proportion of various materials contained in the refuse. In burning such mixtures, common American practice differs from British practice; but in America we much more frequently find the garbage alone to be consumed in the crematory, which, if we judge from English statements on the subject, does not appear to be done at all in Great Britain.

Let us now consider the ideal requirements of a crematory to burn kitchen garbage inoffensively, at least expense, leaving

out of consideration the utilization of the heat produced. Kitchen garbage is (or should be) collected in water-tight cans or water-tight wagons. Frequently it is brought to the crematory floating in its own liquids. The treatment must be able to accomplish the following things:

1. To drain off and dispose of the free water, either into a sewer or into a part of the furnace where it may be evaporated without offense.

2. To evaporate the water absorbed in the drained garbage, and in chemical combination therewith, so as to render the hydrocarbons of the garbage capable of being burned.

3. To completely oxidize all substances capable thereof.

4. To raise all products of distillation, including the evaporated water, and all air introduced in the process of feeding and stoking, to a temperature sufficient to prevent odors in the chimney gases. This temperature is theoretically not less than 1200° F., and should be higher in practice.

Besides these requirements, the cost of operation must be considered. To keep this a minimum, we must provide as follows:

5. Keep the first cost as low as possible.

6. Select a design that will require the least repairs.

7. Select a crematory that will not require excessive labor for its operation.

8. Select a design that will be economical in the use of fuel.

Items 6, 7, and 8 are of far more importance than Item 5, as the yearly operating expenses and maintenance might readily exceed the first cost in a poorly designed furnace.

There are a number of furnaces that will accomplish the purposes 1, 2, 3, and 4, if cost is not especially regarded; and it is quite possible for any good steam engineer with experience in boiler-settings, or in the construction of kilns, to design

a crematory that will be effective without infringing any of the numerous patents in the field, provided that he informs himself as to avoid patented features; but he would be put to considerable trouble to devise a furnace that would also be economical and reasonable in first cost, and avoid all infringements of existing patent rights.

In considering the principles involved in constructing a garbage- or refuse-furnace the character of the materials to be handled, and the conditions imposed by the collection system adopted, cannot be ignored. If the material to be destroyed contains a large proportion of combustible material, and not more than 30% of moisture, it may be stored in the crematory building as received from the collecting wagons, and fed into the furnaces as desired, as any other fuel would be fed. If the combustible part is a sufficiently high percentage at all times to burn with proper supply of air, and produce a temperature of 2000° or more in the combustion-chamber without the addition of other fuel, no other fuel will be required to prevent odors, especially if the furnace operates continually, day and night. If the furnace operates intermittently, as during the day only, a fuel-fire must be built to start the furnace each day, to prevent odors at starting. For a furnace burning garbage of this character a forced draft is highly desirable, because of the depth of material in the bed of fire on the grate, its tendency to become clogged, and the necessity of having stoke-doors open a considerable part of the time.

But wherever the refuse material contains 40% or more of moisture (generally where less) preliminary drying must take place before actual burning; and the gases from preliminary drying are, in all cases, very highly offensive. They must be reheated by some effective means, in the presence of a sufficient quantity of air, to the temperature of ignition of

hydrocarbons—not less the 1200° F. and preferably much higher. This reheating may be accomplished in several ways, some of which are patented, while others are not. Most American furnaces provide for this purpose a separate fuel-fire over which the gases of distillation or drying must pass. This should always be followed by a combustion-chamber of ample capacity to effect complete mixing and burning of the vapors.

American crematories differ much in the degree to which the fuel value of the garbage is made use of, and the consequent economy in fuel. In the following chapter will be given a complete review of the principles upon which crematories are built in America, with a corresponding classification of patents issued in the United States, bearing upon crematory construction.

The burning of refuse need not be complicated by a consideration of the utilization of the waste heat for steam production, for it is obvious that if the combustion is complete, and the fuel temperature of the waste gases is never lower than 1200° F., some heat is always available for steam raising. Whether it will pay to use it for that purpose will be considered elsewhere in this work. 1200° is stated as a minimum temperature to which gases must be raised *in the presence of an excess of air*. It must not be assumed by the engineer that it is safe to design with the purpose of reaching this temperature only. The gases in any furnace are at all points differently mixed; and unless the average temperature in the furnace gases is considerably above 1200° F., odors will be discharged from the stack, owing to incomplete combustion in portions of the furnace, even when the average temperature is above that of ignition.

FIG. 3.—Exterior View of Dixon Garbage Crematory at South Bend, Ind.

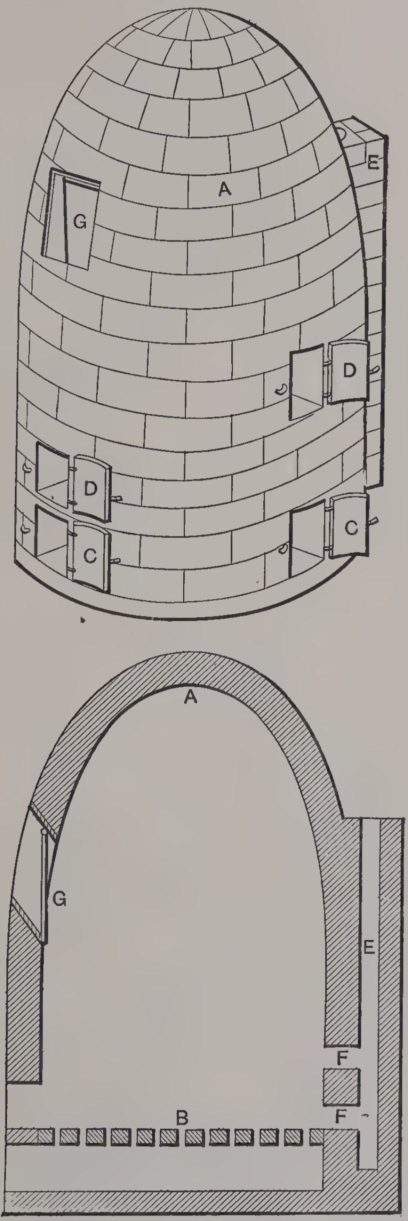

Fig. 4.—I. O. Smith Refuse Burner.

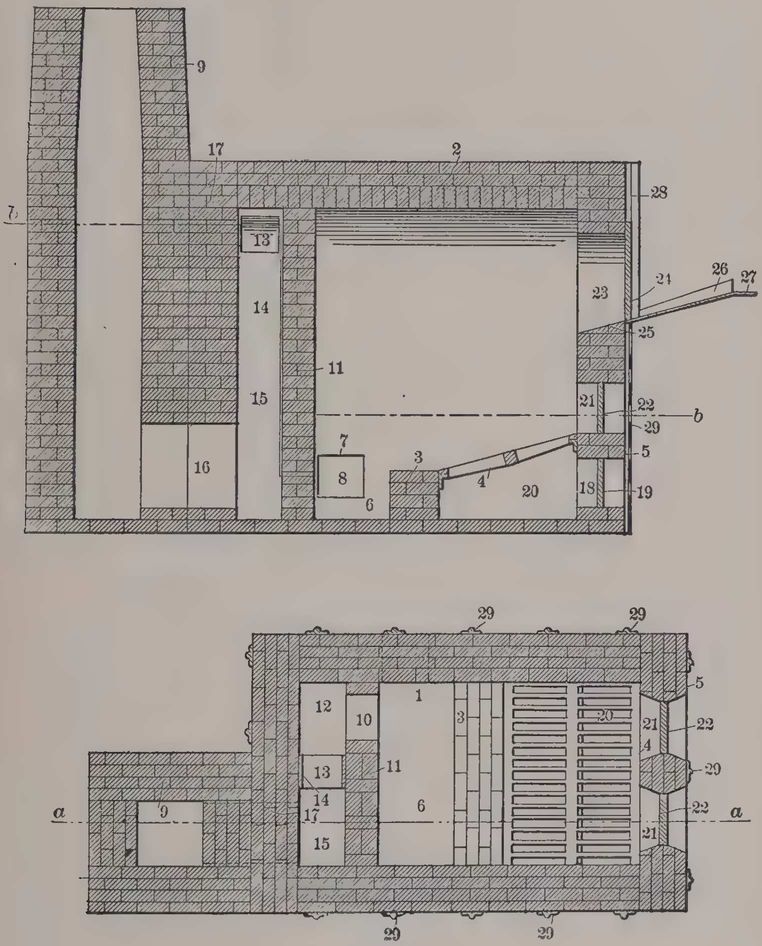

Fig. 5.—Hall Rubbish Crematory.

CHAPTER IV.

THE PRINCIPLES OF CREMATORY DESIGN.

We will first, for convenience, classify crematories with reference to the amount of provision made in them for drying garbage before burning it. In Class 1 there is no preliminary drying; in Class 2 but slight preliminary drying; in Class 3 the preliminary drying is the main object of the furnace. Classes 4 and 5 endeavor to combine the drying advantages of Class 3 with more efficient devices for using the heat of burning garbage previously dried. We proceed to a more specific definition and description of each class.

Class 1. Crematories in which Refuse is Burned on a Grate without any Preliminary Drying.

Furnaces of this class are adapted for burning waste-paper, boxes, house-sweepings, or other combustible wastes, without the use of auxiliary fuel-fire. All the essential features of a furnace of this class are shown in Fig. 4, which is taken from the drawings of patent No. 99,793, dated Feb. 15, 1870 to I. O. Smith.

These elements are a large up-draft grate, a combustion-chamber of ample size to receive and to burn the refuse, with an outlet to the stack from near the bottom of the combustion-chamber.

A patent drawing showing all of the elements usually

employed in furnaces of this class, with some others, is that of No. 655,975, here shown in Fig. 5. In this furnace the rubbish is pushed through the opening 25, and falls upon the grates 4. The combustion-chamber 1 is large, to permit the gases to mingle thoroughly; the outlet from it, 10, at the bottom. The vertical passages, 12 and 15, are to secure further mixing before the gases pass into the chimney.

Any capable engineer may design a furnace of this class without infringing upon unexpired patents, but to do so he must be familiar with the combinations patented by others. Patents in this class are as follows:

(6600 reissue) 99,793 I. O. Smith.
116,829 George Goodsell et al.
371,203 W. Mann.
655,975 J. Hall.
762,344 H. E. Parson.
762,345 H. E. Parson.

There are many other patents that might fall within this class, but are particularly applicable to burners for sawmill refuse. These have been omitted as not bearing directly upon the subject of this volume.

Class 2. Crematories in which Refuse is Burned on a Grate, with but little Preliminary Drying on an Adjoining Hearth.

This class includes the so-called "British types" of refuse destructors, or crematories. They occupy an intermediate position between the furnaces of Class 1 and those of Class 3, hereafter described.

In Great Britain the garbage, refuse, and ashes are usually

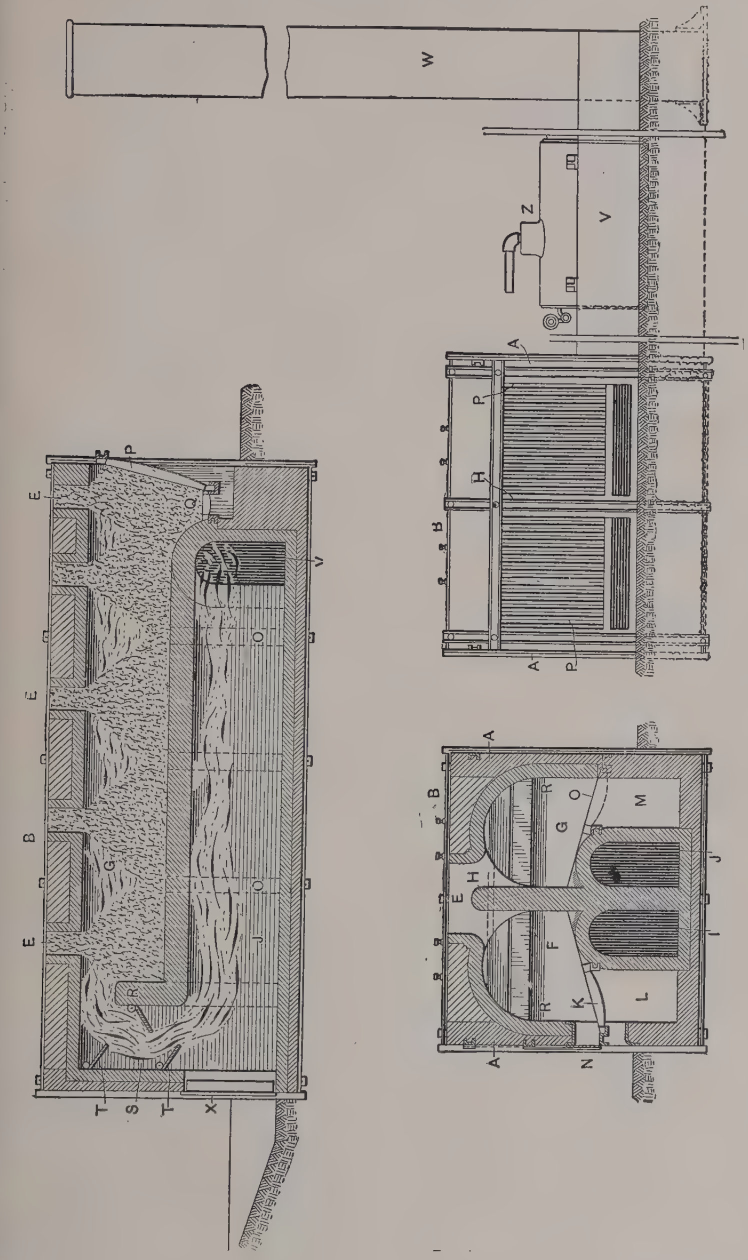

FIG. 6.—Horsfall Cremating Furnace.

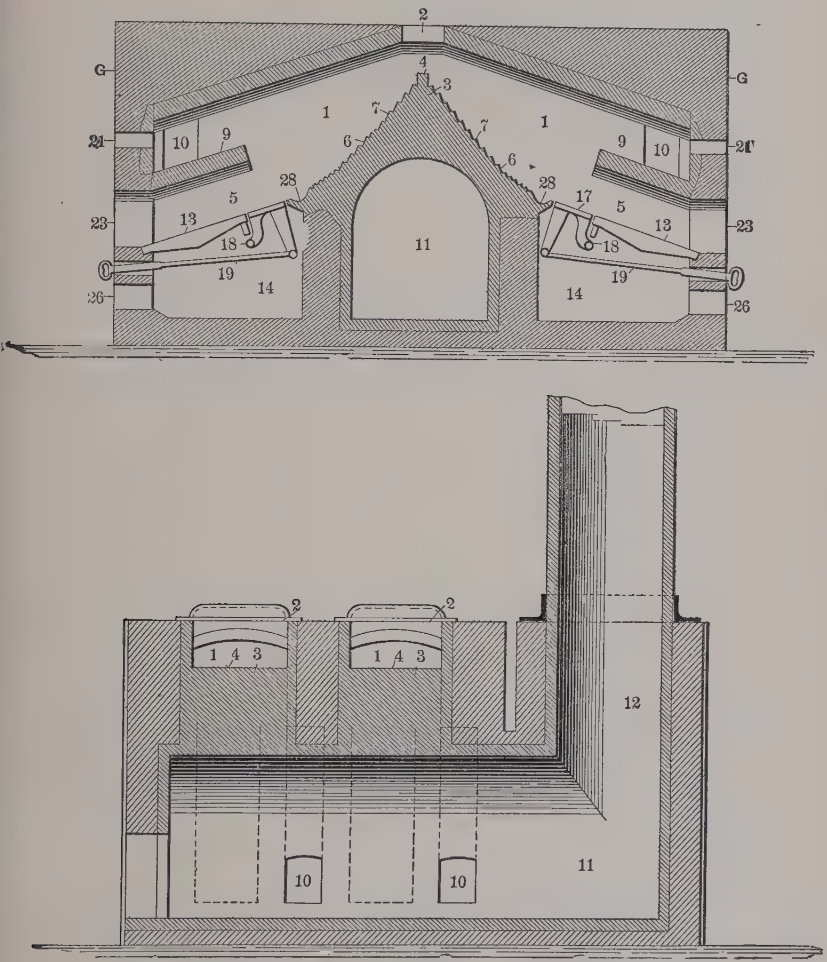

Fig. 7.—Wright Incinerating Furnace.

collected together, and this mixed refuse burned in a crematory on an up-draft grate, with or without auxiliary fires to consume odors. The prime condition necessary for doing this satisfactorily is to maintain a fire with a deep bed of burning material, so that moist material fed on the fire from above will not smother the fire. This involves the employment of a very strong draft, preferably a forced draft applied below the burning grates.

Furnaces of this kind are almost always provided with a boiler plant to generate steam to utilize the heat in the gases of combustion, the steam being necessary to produce the forced draft. The surplus steam may be used for power purposes; but the quantity of power that can be generated from a given amount of refuse, under most favorable circumstances, is not a matter upon which agreement has been reached by those most familiar with the problem of refuse cremation.

In spite of the claims of English furnace-builders and their representatives, and in spite of the often-repeated expressions of opinion by writers on this subject, the prevailing opinion in America is that to reburn household ashes in a crematory to raise steam does not pay, but that it is better to haul such materials direct to the dump, and to burn only the garbage and litter. A discussion of this matter is given in another chapter.

As illustrations of this class of furnace, Fig. 6 is taken from patent No. 763,562 to W. Horsfall, and Fig. 7 from patent 575,088 to W. B. Wright. These diagrams show cross-sections through pairs of cells, there usually being several pairs of cells connected to one flue leading to the boiler.

The Horsfall patent is but one of several granted to a well-known English firm. In the one selected here the refuse is dumped into the cells from above through feed-holes, each

of which communicates with two cells of the pair. It falls upon a hearth, whence it is raked forward upon the burning grates, designated by the letter *K*. The combustion is perfected in the long flues *I* and *J*, whence the gases pass to the boiler plant.

Patents covering crematories of this class are as follows:

63,558 (1887) J. E. Stafford et al. (Br.).
372,172 J. Richmond et al. (Br.).
429,626 W. Horsfall (Br.).
464,171, E. W. Cracknell.
492,987 E. C. Morse (U. S.).
543,134 W. J. Hull.
553,574 C. Thackeray (Canada).
574,774 S. J. Beaman and J. Deas (Br.).
575,088 W. B. Wright (U. S.).
615,400 J. J. and T. F. Meldrum (Br.).
658,695 J. T. Wood and J. A. Brodie (Br.).
661,463 J. Wilkie (Br.).
664,039 W. J. Glen (Br.).
664,980 C. Thackeray (Can.).
672,242 J. C. H. Stut.
763,562 W. Horsfall (Br.).

"Br." indicates that the patentee is British, "Am." American, and "Can." Canadian. Those contemplating the design of plants to burn mixed refuse for the purpose of generating steam should be familiar with the details of structure, and the claims allowed, in all of the foregoing patents. Steam-generating plants are also found under other classes.

The Thackeray furnace is illustrated in Fig. 33, and described in Chapter VI; the Wright furnace is described in Chapter VI; the Meldrum furnace is illustrated in Fig. 43, and described in Chapter VII.

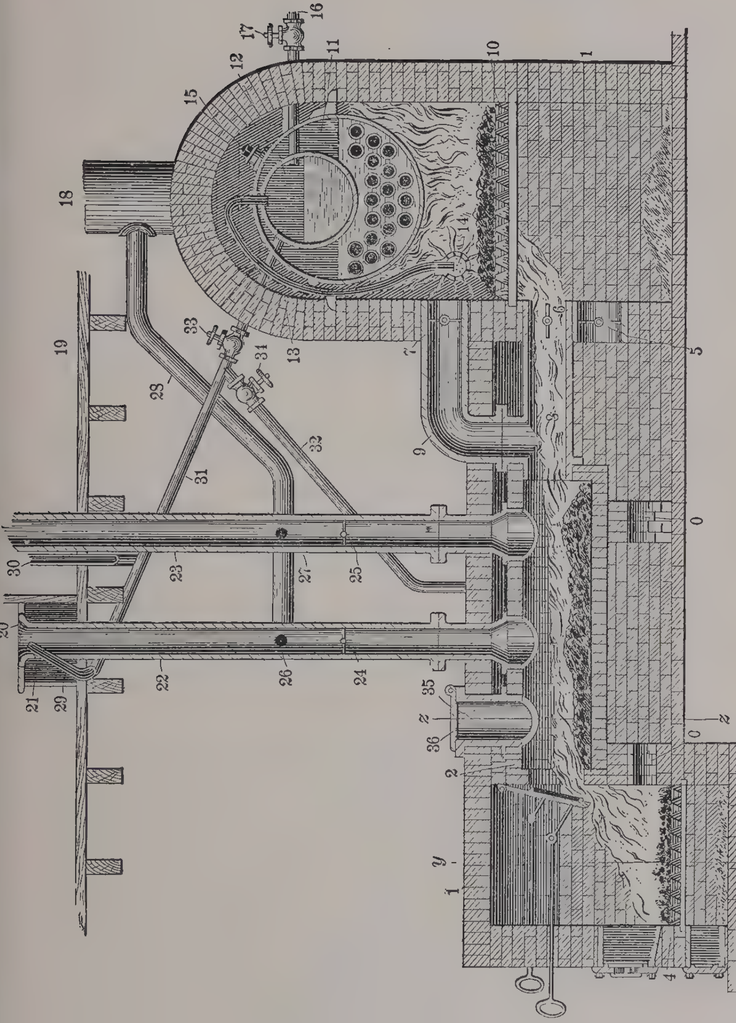

Fig. 8.—Eagle Garbage Crematory.

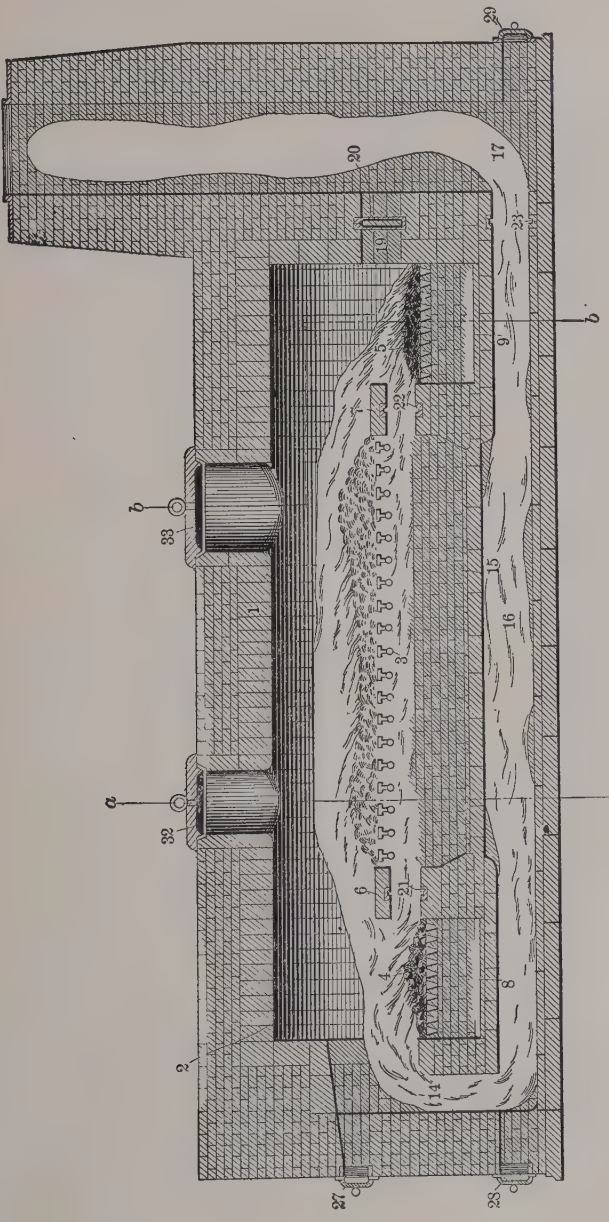

FIG. 9.—Warner Garbage Furnace.

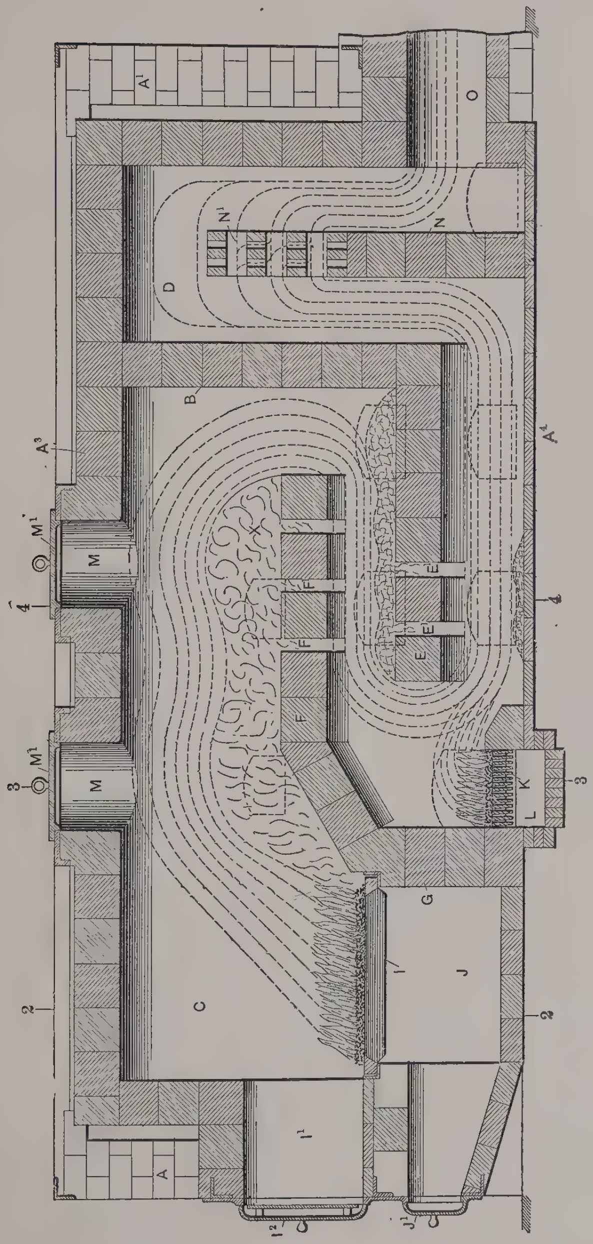

FIG. 10.—Boulger Garbage Crematory.

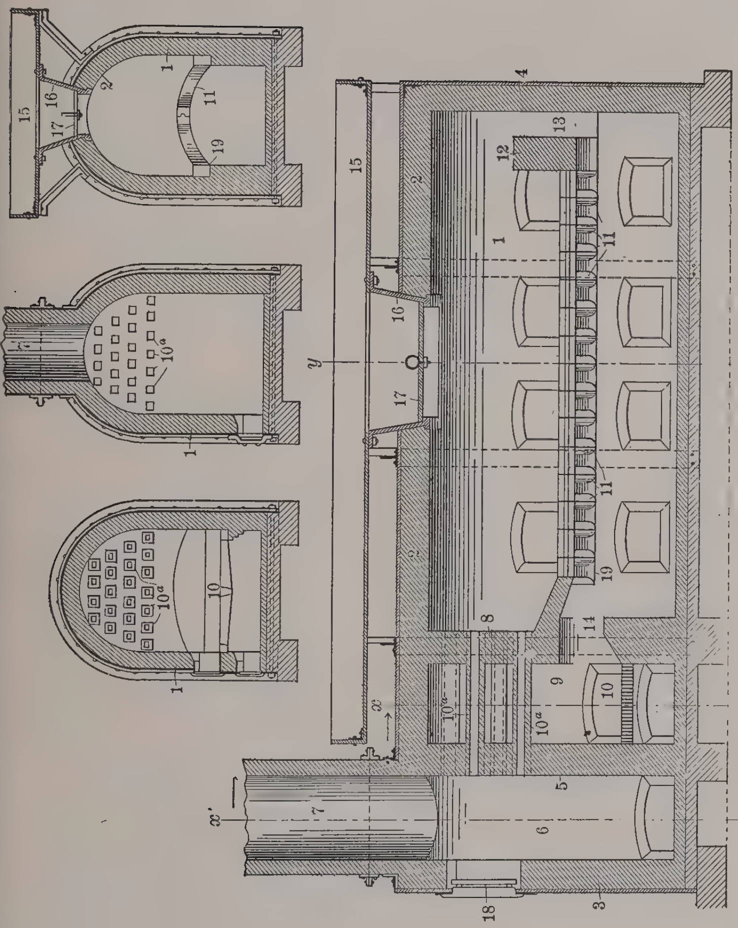

FIG. 11.—Little and Shaw (Dixon) Garbage Furnace.

Class 3. Furnaces in which Garbage is Burned on a Hearth or Grate by Subjecting it to Intense Heat from Fuel-fires on other Grates.

Furnaces of this class have sometimes been called the "American type," because they have been used more extensively in this country than other types. This is undoubtedly due, in a large measure, to the American practice of collecting kitchen garbage, or "swill," separately, and burning it, unmixed with other wastes, in a garbage crematory. Such material cannot be burned at all in furnaces of Class 1, or in furnaces of Class 2, unless mixed with a large portion of other material

The essential elements of crematories of this type are a large hearth, grate, or platform upon which the garbage is received and "incinerated," or reduced, by the flames of a fuel-fire producing the heat necessary to reduce the garbage, while a second fuel-fire to raises the gases to a high temperature after they have passed over the garbage before they are discharged into the atmosphere. These elements are all sold and unpatentable, but there are man patents covering various methods by which they can be combined with others.

For illustration Figs. 8, 9, 10, 11, and 12 are taken from the drawings of patents, as follows: 8 from No. 372,305 to A. Engel; 9 from No. 468,851 to G. H. Warner, 10 from No. 773,920 to B. Boulger; 11 from No. 789,329 to E. J. Little and D. C. Shaw, and12 from No. 530,623 to J. E. McKay.

The Engel, the Boulger, and the McKay furnaces are described in Chapter VI, as products of American builders. Little and Shaw's patent is owned by the Dixon Company, and described as their product in Chapter VI. Other furnaces of this type are illustrated in Figs. 32 (Brownlee), 36 (Stringfellow), and 12 (Walker).

The fuel economy of these furnaces, and the heat recoverable by a boiler plant in connection with the crematory, are discussed in another connection.

Patents for crematories of this class are as follows:

372,305 A. Engle.
408,559 H. W. Whiting.
411,963 B. C. Heavey.
413,832 A. Patrick.
448,115 A. Brownlee.
461,327 S. W. Dixon.
468,851 G. H. Warner.
468,852 G. H. Warner.
490,582 Wm. McClave.
496,046 D. F. Donegan.
501,181 S. H. Brown.
501,458 N. Dowling.
503,845 W. H. Garretson and S. B. Tainter.
505,656 B. C. Heavey.
517,301 W. Risley.
517,816 S. W. Dixon.
530,623 J. E. McKay.
532,971 T. A. Knapp.
533,448 N. Dowling.
535,292 De Haven Lance.
537,181 B. Boulger.
537,339 A. Brownlee.
537,801 S. H. Brown.
583,663 U. K. Stringfellow.
584,434 R. L. Walker.
644,966 S. H. Brown.

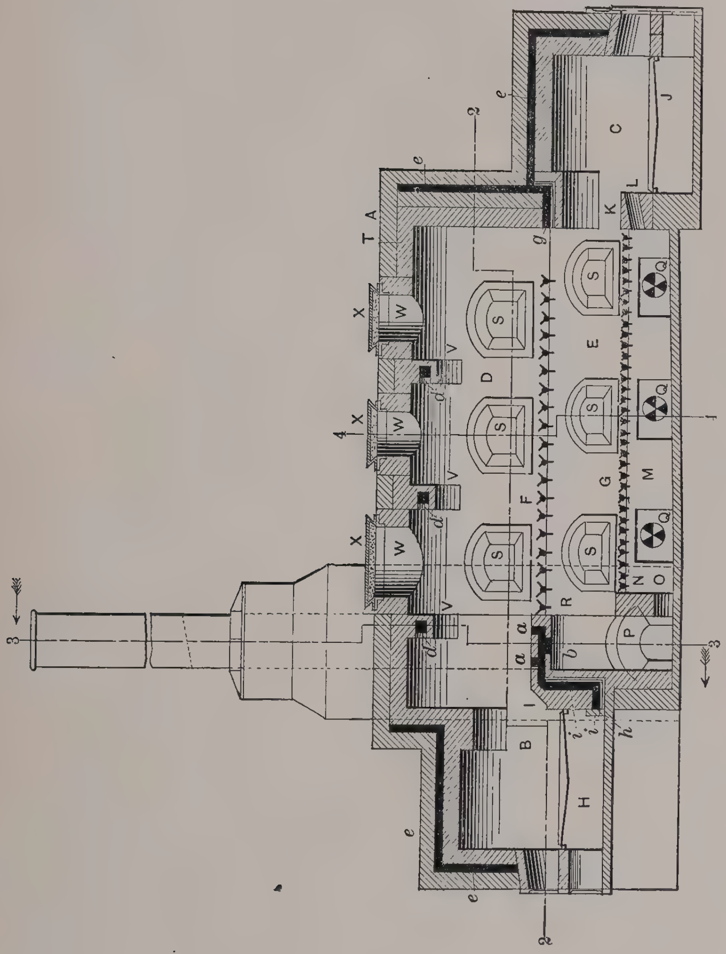

Fig. 12.—McKay Crematory.

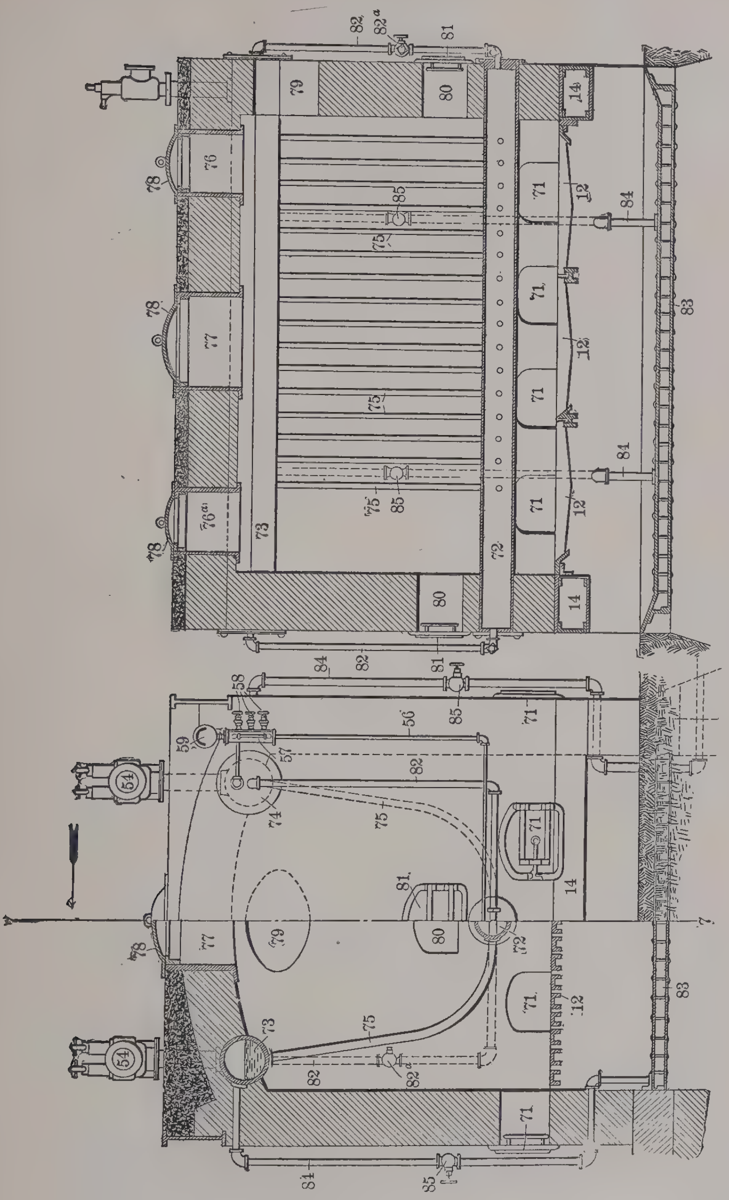

Fig. 13.—Decarie Garbage Crematory.

667,445 E. J. Little et al.
674,319 W. Risley.
709,946 R. L. Walker.
724,898 E. J. Little et al.
766,848 F. P. Smith.
766,849 F. P. Smith.
773,920 B. Boulger.
776,605 J. Lindsay et al.
789,329 E. J. Little et al.

Class 4. Crematories in which Garbage is First Extensively Dried on a Hearth or Grate, and then Stoked to Another Grate to be Burned as Fuel.

Furnaces of this kind combine, or attempt to combine, the principles of Class 3 with those of Classes 1 and 2, the object being to make the burning garbage produce heat to dry other garbage, and to prepare it for burning.

For illustration, Fig. 13 is taken from patent No. 749,269 to F. L. Decarie, and Fig. 14 from patent No. 783,476 to F. P. Smith. The fuel economy of such furnaces is discussed elsewhere.

Patents for crematories in this class are as follows:

462,035 M. L. Davis.
523,699 J. B. Wayt.
596,421 (reissue 12,059) F. L. Decarie.
658,658 J. F. Lester and L. A. Dean.
675,884 L. A. Dean.
749,269 F. L. Decarie.
757,149 H. B. Smith.
772,681 F. L. Stearns.
783,475 F. P. Smith.

783,476 F. P. Smith.
800,177 F. P. Smith.
803,650 F. G. Wiselogel.

Other figures showing furnaces of this class are Figs. 30 (Davis), 39 (H. B. Smith), 40 (F. L. Stearns), and 41 (Weislogel). These furnaces, as well as tho seof Smith and Decarie, are described in Chapter VI.

Class 5. Crematories in which Gases of Combustion from Burning Garbage in One Cell are Passed Through Other Cells to Dry Garbage Therein.

This class usually requires some arrangement of dampers for changing the path of the fires from the burning grates to the stack. Fig. 15 from patent No. 584,434 to R. L. Walker illustrates the principle in simple form.

Patents for crematories in this class are as follows:

535,292 De Haven Lance.
584,434 R. L. Walker.
709,946 R. L. Walker.
766,848 F. P. Smith.
766,849 F. P. Smith.
783,476 F. P. Smith.

The above are also arranged in the other classes.

Miscellaneous Crematory Patents of interest to those engaged in the business of crematory design and construction, or desirous of looking thoroughly into what has been proposed or attempted in crematory design, are given in the following list. These apply to devices not falling readily into any of the classes given in this paper. A number of them are for crematories provided with rotary dryers; many for crematories employing conveyors for garbage and ashes; some of them apply to reduc-

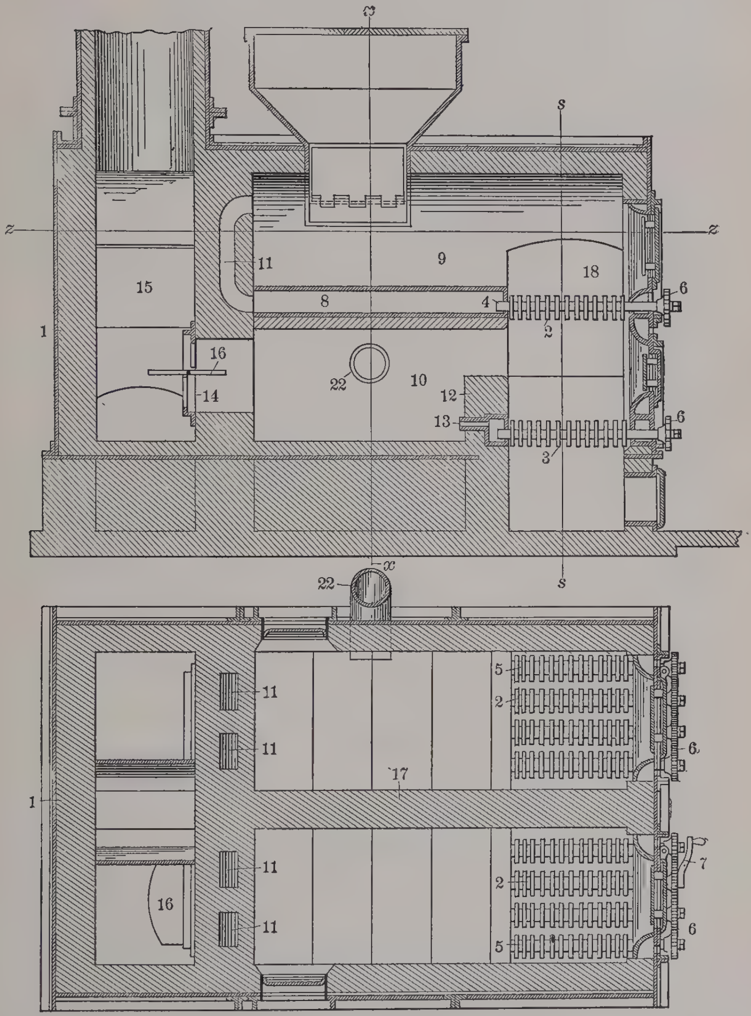

FIG. 14.—F. P. Smith Garbage Furnace.

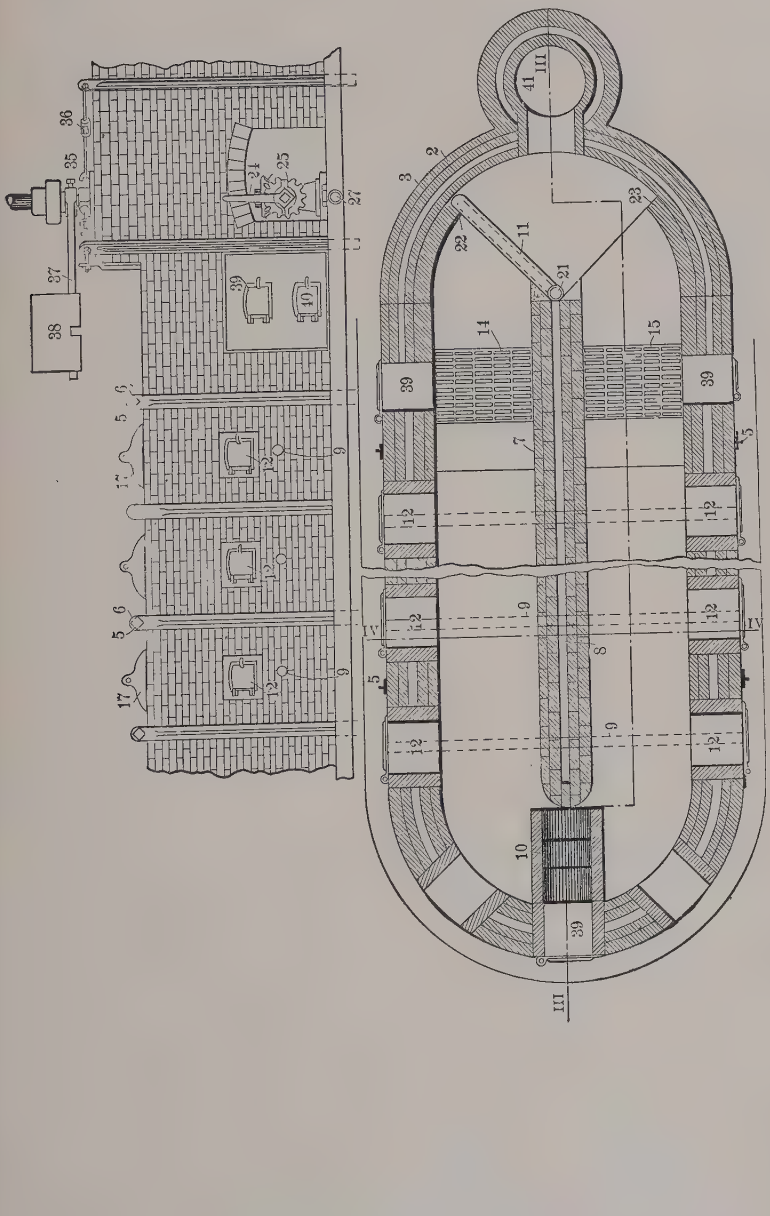

FIG. 15.—Walker Garbage Crematory.

tion plants only, and some to devices used in connection with crematories, such as hoppers and grates. There are many other patents of interest to crematory builders, not classified with crematories by the patent office.

195,495 E. B. English and W. H. Burr.
211,505 Henry R. Foote.
215,957 W. J. Morris.
338,124 A. K. Brown.
352,857 P. C. Close.
357,108 E. G. Teed.
370,223 M. Vincent.
371,842 J. Hewes.
379,189 J. Vladyke and W. M. Mitchell.
390,922 A. Vivarttas, J. K. Caldwell, and H. D. Hughes.
391,614 J. Hoskin.
398,671 E. G. Teed.
409,022 R. De Soldenhoff.
446,340 W. L. Fuller.
462,891 T. W. Carrico.
474,933 John Wilson.
481,147 John H. Parke.
484,774 F. Cain.
488,169 J. C. Kessler.
501,760 C. J. Best and W. A. Hall.
501,761 C. J. Best and W. A. Hall.
503,073 T. W. Carrico.
508,511 A. Engle and S. C. Thompson.
516,706 W. S. Johnson.
517,288 J. E. McKay and A. G. Delanoy.
520,105 J. F. Chazotte.
522,331 G. S. Strong.

523,478 T. P. Mahon.
524,687 E. S. Ransome.
524,688 E. S. Ransome.
526,283 J. C. Anderson.
526,284 J. C. Anderson.
526,516 T. M. Clark.
529,236 C. A. Ball.
539,096 J. J. Storer.
539,245 J. C. Anderson.
539,771 D. E. Healy.
546,438 W. Swindell.
546,497 M. V. Smith.
548,254 W. Horsfall.
551,342 C. A. Wentworth.
551,849 R. A. Chesebrough.
551,850 R. A. Chesebrough.
554,453 I. S. McGeihan.
556,420 W. L. Johnson.
562,845 I. S. McGeihan.
573,605 C. W. Lent.
575,981 W. G. Parr.
577,184 E. De La Chapelle and J. Pearce.
580,078 Chas. Asbury.
581,016 W. S. Richardson.
585,597 R. C. Sayer.
588,998 J. J. Kennedy.
600,855 J. F. De Bonardi and A. D. F. De Villepigue.
606,254 F. E. Swift.
607,553 I. D. Smead.
617,254 J. H. Mitchell, H. G. Downton, and W. H. Nicholls.
631,457 F. W. Dennis.
633,299 Carl Weginer.

633,300 Carl Weginer.
633,301 Carl Weginer.
639,649 J. A. and W. K. Baker.
644,504 S. W. Dixon.
645,131 J. T. Robbins.
645,349 J. Conley.
647,432 C. T. Whedon.
667,013 W. S. Hull.
667,015 W. S. Hull.
669,054 Jas. L. White.
669,632 F. Gorman.
688,090 W. S. Hull.
688,947 J. L. Bell and J. T. Subers.
674,992 H. S. Woolley.
691,328 I. D. Smead.
699,635 R. Robinson.
719,545 C. A. Williams.
723,959 W. M. Wheildon.
731,032 F. A. Forsyth.
747,488 T. Rooke and J. Thrush.
750,457 F. E. Haycock and J. McDermott.
755,622 E. E. Hill.
769,872 H. Ochwat.
783,473 F. P. Smith.
806,127 F. W. Field.

Fig. 29 is reproduced from one of the sheets of the drawings of patent No. 390,922 to A. Vivarttas. It is given to show the complexity of some of the designs attempting heat-regenerative construction—an attempt made in several of the miscellaneous patents listed. Fig. 34 illustrates patent No. 554,453 to I. S. McGiehan—a rotary dryer arrange-

ment, which will be found also in patents Nos. 215,957 and 539,096. Fig. 35 illustrates the arrangement adopted by De La Chapelle and Pearce. Fig. 37 illustrates Smead's rotary grate-furnace, patent No. 607,553. Similar arrangements are found in Nos. 545,975; 548,254, 575,981, and 669,632.

These diagrams are all found in connection with descriptions of particular installations in Chapter VI.

There have also been issued about a dozen patents for portable or traveling crematories, intended to burn garbage as it is collected. These can be made to burn garbage, but the quantities that can be handled are too small for any machine of a size that can be transported on ordinary streets to make the plan economical, if sufficient ingenuity be exerted to make it practicable; and such machines are not likely to ever come into permanent service.

Crematories of Classes 3 and 4 are of the most interest to the American public at the present time, because in America the separate collection system has become established, and its superiority from both sanitary and economical points of view recognized; and crematories of these classes are practically the only ones that will burn kitchen garbage alone, without producing offensive odors, though some British furnaces of Class 2, such as shown in patents Nos. 372,172, 615,400, and 763,562, may almost be assigned to Class 4 also. But the arrangements of these are not as effective for drying purposes as in the latest designs in Classes 3 and 4.

One of the most important features in the design of furnaces in Classes 3 and 4 is the garbage-receiving hearth or grate, or other supporting device. This is located in the combustion-chamber. It is usually subjected to heat from both above

and below, and often to a variation of temperature of from freezing (when it receives frozen garbage) to 2500° F., when the garbage is in the last stage of incineration. It is difficult to secure any material or design that may be subjected to this wide variation in temperature, as well as to the mechanical strains incidental to charging and stoking, for any great length of time. There are several methods of construction of this receiving platform, or grate, that have been found practicable, but the relative merits of which are among the chief matters of dispute among crematory builders. These methods fall into the following groups:

Group 1. Solid Garbage Grates of Cast Iron.—Such grates, if cleverly designed, answer fairly well when fire passes only above them. When fire passes both above and beneath, such grates are serviceable only when never subjected to a temperature above 1000° F. (or less), which is below that of combustion. Some cooling of grates may be effected by garbage in contact with them. The last patent showing solid cast-iron grates was applied for Jan. 17, 1894—twelve years ago. All later patents employ other construction. The patents showing solid cast-iron grates in their drawings are:

462,035 M. L. Davis.
468,851 G. H. Warner.
468,852 G. H. Warner.
501,181 S. H. Brown.
503,845 W. H. Garretson and S. B. Tainter.
517,816 S. W. Dixon.
530,623 J. E. McKay.
537,801 S. H. Brown.

Group 2. Solid Garbage Grates of Fire-clay.—These, if made of the highest grade of fire-clay, with the lowest pos-

sible coefficient of expansion, will resist temperatures up to 3000° F., but they are injured by sudden cooling and by the action of the water when wet garbage is dumped upon them, and they wear rapidly under the process of stoking. Patents showing them in drawings are as follows:

411,963 B. C. Heavey.
505,656 B. C. Heavey.
517,816 S. W. Dixon.
523,699 J. B. Wayt.
537,181 B. Bougler.
577,184 E. De La Chapelle et al.
644,966 S. H. Brown.
658,658 J. F. Lester and L. A. Dean.
667,445 Eugene J. Little et al.
672,242 J. C. H. Stut.
683,970 D. W. McDade.
699,635 J. Robinson.
724,898 Eugene J. Little et al.
773,920 B. Boulger.
789,329 E. J. Little.

Group 3. Garbage Grates of Hollow Iron Cooled by Water Circulating within, as in a Steam-boiler.—These will resist the action of the heat, by generating steam within the tubes, which necessarily reduces the commercial efficiency of the furnace, unless all of the steam generated is used for commercial purposes. Because of the mechanical strains to which a garbage grate is subjected, it is manifestly unsafe to carry in its tubes a high steam pressure, which limits the usefulness of the steam generated in such tubes. Crematories employing water-cooled garbage grates are shown in the drawings of

the following patents; a number of which are for combination crematories and water-heaters, intended for use in hotels and apartment houses:

377,651 E. G. Teed.
479,405 A. G. Delanoy.
496,544 W. D. Walters.
517,288 J. E. McKay and A. G. Delanoy.
537,339 A. Brownlee.
749,269 F. L. Decarie, reissue 12,059.
757,149 H. B. Smith.
583,566 A. W. Colwell et al.
583,663 U. K. Stringfellow.
596,421 F. L. Decarie, reissue 12,059.
639,533 M. J. Cragin.
718,490 J. Mann.
763,410 A. Long.
766,153 G. W. Mathews.
773,248 M. J. Cragin.
778,954 J. J. Dubé.
787,771 F. C. Kummerow.
803,650 F. G. Wiselogel.
805,256 J. G. Branch.
807,219 G. Thumm.

Group 4. Garbage Grates of Hollow Cast Iron, Cooled by Air Circulated through them. — These grates are maintained at a much higher temperature than those of Class 3 (which are at the temperature of steam within them), but at a lower temperature than those of Class 1. The heated air may be wasted, or used for combustion in the furnace. The list of patents for crematories employing garbage-receiving grates of iron cooled by air circulating through them is as follows:

408,559 H. W. Whiting.
517,301 W. Risley.
766,848 F. P. Smith.
766,849 F. P. Smith.
783,473 F. P. Smith.
783,475 F. P. Smith.
783,476 F. P. Smith.
800,117 F. P. Smith.

It should be remarked that some of the patents instanced under these four groups do not make any claims as to the grates at all; others claim particular forms of grates; while others claim grates of certain kinds in combination with other features in the furnace. *Grates of all four groups may be used by any designer, provided he avoids the patented features*, which are, however, numerous.

It seems strange that with so many patents granted in this field, comparatively few firms have remained in the business of crematory construction, or perfected their apparatus to commercial form. This is due in part to the great difficulties of designing a crematory that will be effective, durable, and cheap, both to build and to operate, and partly to the many unsuccessful attempts to build crematories by parties not competent to build good ones, whereby the public has been victimized and the crematory business injured. It is probably true that no designer or engineer has made a real success of the first garbage crematory without altering the original design after building; and it is undoubtedly true that no firm now engaged in this business builds crematories identical in design with the first ones built under its patents. Most builders who continued some time in business have taken out a number of patents in succession.

FIG. 16.—Crematory and Building, League Island Navy Yard. (Morse-Boulger System.)

CHAPTER V.

THE COST OF OPERATING A CREMATORY.

THE total cost of disposing of wastes by cremation is made up of the cost of collection and hauling to the crematory, the cost of hauling ashes and clinkers from the crematory to the dumping-ground, and the cost of cremation. This last-named cost may be separated into interest on investment, maintenance and depreciation, and operating expenses.

Maintenance and depreciation charges are large in all crematories, but they depend to a great extent upon the character of the workmanship and the quality of the materials used, as well as upon the design. A poorly constructed crematory, even if of meritorious design, will not last a year; while a well-constructed one of good design should last ten years or more, with occasional replacement of worn parts. Crematories of any of the classes named in this paper can be built to last ten years or more, with reasonable renewal of parts.

Operating expenses are of the greatest importance.

For a crematory operating twenty-four hours a day, every day in the year, they may amount to 50% or 75% of the first cost per annum. Manifestly, if the operating expenses can be materially reduced, even at the cost of rendering the maintenance expenses somewhat greater, the matter should be considered.

With present prices of fuel, in large furnaces, the operating

expenses are in the neighborhood of 50 cents per ton of kitchen garbage destroyed. The maintenance is from nothing to $1.00 per ton, according to the design and materials employed, and the depreciation is from 10% to 50% per annum. In some furnaces a less cost of operation is claimed; but the claim of each builder should be subjected to a careful investigation before being accepted as justifiable; and it is proposed to set forth here some of the facts that limit the cost of operation to certain minimum values, which may be approached, but never reached.

Kitchen garbage contains 80% or 90% of water, including that in chemical combination, and 20% to 10% of combustible material, equal in fuel value to about half its weight of good coal. It should be equivalent in heat-producing content, then, to between 5% and 10% of its weight in coal. One ton of garbage should then be capable of producing as much heat, if ideally burned, as 100 to 200 lbs. of good coal.

Now 1 lb. of good coal will evaporate in a steam-boiler about 12 lbs. of water. In a crematory, however, the water in the garbage must be both evaporated and raised to a high temperature to destroy odors. To do this it requires more heat—about 1 lb. of coal, or equivalent, to each 8 lbs. of water evaporated. If a ton of garbage contains 80% water, or 1600 lbs. of water, it would require 200 lbs. of coal to evaporate the water to a temperature that would leave no bad smell in the chimney gases, if the garbage contributed no heat; but if all the heat that could be produced by ideal combustion of the same garbage were used, no coal at all would be required.

But there are other things that consume the available heat other than the evaporation of water—one of these is the radiation from the furnace, but the most important is the heating of surplus air admitted to the furnace, or of water

used to keep grates cool when so employed. To keep the air admitted from being excessive in furnaces of Classes 3 and 4, great care must be exercised to keep the stoke-doors closed, and to admit no more air than is necessary for combustion. As garbage requires very much stoking, because it contains such a small percentage of combustible material, this is a difficult matter, and the provision for stoking without admitting surplus air is an element in the design that should be carefully considered in making selection of a furnace. In some designs, where water is used in the grates, the heat wasted in water-pipes of the garbage grates is a source of excessive loss, unless the steam or hot water, which is necessarily at low pressure, can be made use of. If the garbage-receiving grates can be kept cool enough, by circulating air through them, and if the air so heated is not additional to that required for combustion, it would seem that the maximum practicable heat economy would be secured.

When refuse containing a larger percentage of combustible material is to be burned, the amount of auxiliary fuel required for its destruction rapidly diminishes, and the amount of stoking required becomes greater, per ton burned. A furnace designed to burn kitchen garbage is not equally well adapted for burning trash, though it may be made to answer. Much more air is required for the trash, necessitating larger flues and a larger stack for a given weight of refuse than for the same weight of garbage. A man can stoke from six to ten tons of combustible refuse per day, removing the ashes. This makes the cost of stoking between 15 and 25 cents per ton, according to the wages paid, when the man is kept busy. The same principles of fuel economy apply in burning trash as in burning garbage, but if no auxiliary fuel is required, and if the heat generated is not to be used for power

purposes, the same care is not necessary. The cost of operation is increased by any attempt to conserve steam for power purposes, but often revenue may be derived from steam so produced.

Heat Available for Steam Raising.

In a crematory burning kitchen garbage, whether of Class 3, 4, or 5, no part of the gases leaving the crematory should be at a temperature less than 1200° F., and the average temperature will be much higher, sometimes reaching 2400° F. These waste gases can be reduced to 500° or 600° by installing of a steam-boiler of suitable design, generating steam at pressure suitable for power purposes.

The total heat produced by the burning of one ton of garbage and of the auxiliary fuel is equivalent to that developed by burning some 200 to 400 lbs. of coal, according to the furnace employed; but the gases produced are about twice as voluminous as would be produced if an equivalent weight of good fuel were burned alone. The net result is that it is practicable to regain only about half as much heat, or to generate half as much steam as could be generated by burning coal with the same heat-producing value directly under a steam-boiler; or, in other words, in a furnace properly cremating kitchen garbage, by inserting a boiler between the crematory and the stack, the water that may be evaporated in the boiler will be 1200 to 2400 lbs. per ton of garbage burned, while the coal required in the crematory should not exceed 200 lbs. per ton of garbage consumed.

But if the furnace is burning combustible refuse, such as waste-paper, packing-cases, excelsior, pasteboard boxes, and store refuse, the steam developed by a ton of refuse may be equivalent to that produced by 500 lbs. of coal, or more, in

which case a refuse furnace may be a valuable accessory to a steam plant.

Miscellaneous waste is not so valuable for fuel as selected refuse, but there are many cities where, if carefully collected and scientifically burned, it may develop thousands of horse-power continually.

The problem of steam generating from the heat in the waste gases is one that must be solved with reference to the market for the steam, as well as to the quantity and the cost of its production; but in general the following conditions may be assumed as approximately true.

For a Crematory Burning Garbage only.

1. The temperature of the gases where they come in contact with the boiler is about half that of the gases from a good coal-fire; consequently, the boiler must be about twice as large per boiler horse-power generated, as would be required in an ordinary power plant. If fuel is very cheap in the locality where the plant is under consideration, the economy effected by using the waste heat will not pay interest on the increased investment.

2. The temperature and the volume of the gases from the crematory vary so much that the boiler horse-power generated is very unsteady. This makes it necessary to employ an additional boiler, fired separately, to generate enough steam to make the power steady; or to use more coal in the crematory fires than is necessary, which is uneconomical.

3. If the crematory can be operated as an adjunct to a power plant of much larger steam-generating capacity it is working under the most favorable conditions for the utilization of the steam generated. In such a case it may prove

economical to install a boiler in connection with a plant consuming ten or more tons of garbage per day.

4. In all cases, however, the probable economy is not so great that a decision can be reached without a careful investigation of all of the local conditions, including the cost of power generated by other methods; and if there is any doubt as to the immediate demand for the steam produced by the crematory boiler plant, the boiler should not be installed when the plant is built, but a place left for its installation at a future date.

For a Crematory Burning Mixed Garbage and Refuse, not Including Ashes and Cinders.

5. This case is the same as that just discussed, unless there is sufficient combustible material to operate the crematory without the use of any auxiliary fuel, and it probably will not be feasible to get along without other fuel unless the refuse is dry, collected separately from the garbage, and unless for every ton of garbage there is 500 pounds or more of such combustible refuse. Of course, conditions and furnaces vary so much that such an estimate as this can be only approximate. It is based upon a study of the heat theoretically required, and probably represents a more economical combustion than can be secured in practice.

6. Where garbage and refuse are collected separately and brought to the crematory, it frequently happens that there is as great weight of refuse as there is of garbage. When there is more than half the weight of refuse that there is of garbage, it should not be necessary to burn any auxiliary fuel, and a larger amount of heat becomes available for steam generation. If the amount of garbage and refuse to be destroyed is not more than forty tons per day, or thereabout, it is probably best to burn it all in one furnace, or set of furnaces; but if the amount is

greater, and if the market conditions justify the raising of steam, the garbage and the refuse can be burned more economically in separate furnaces, the refuse being treated as fuel of poor quality.

Where Refuse is Burned Separately.

7. Where refuse is burned separately, with the purpose of generating steam, furnaces of Class 1 answer very well if the material is collected dry; but if it is wet, furnaces of Class 2 are better adapted. The difficulty and lack of economy arise useally from admitting too much air during charging and stoking. This is not as great a difficulty when forced draft is used. Furnaces of Class 4 may also be used for this service, especially when the material is very wet; but those of Class 3 are not as well adapted for burning refuse to generate steam.

8. When ashes and cinders are mixed with the refuse furnaces of Class 2, with forced draft, are preferable. In this case forced draft is necessary to secure combustion of the cinders.

The reburning of ashes with refuse is a practice that the writer believes should be discouraged, although he is aware that several writers on this subject advocate this upon grounds of economy. It is stated that the emptyings of ash-barrels contain not less than 20% and frequently 30% by weight of combustible material, which can be oxidized in a properly constructed furnace, with a production of steam. Suppose that the fact that 30% of the weight is combustible be admitted, the conclusion that it can be utilized economically under ordinary circumstances is fallacious, as will appear from the following considerations:

(*a*) If 30% is combustible, 70% is not, and 70% must be passed through the furnace, heated to the temperature of clinker say (2000° F.), and dumped into the ash-pit. This heat is largely wasted, and it represents the heat produced by the

combustion of considerable fuel; probably one-third of the available fuel in the cinders, leaving only 20% of the original weight of ash and cinders available for other purposes.

(*b*) It is estimated by those who advocate this system that one-third of the steam generated is required to keep up the forced draft necessary to burn a fuel of this character. This leaves two-thirds of 20% = 13.6% of the original weight available for other purposes.

(*c*) The 70% ash must be hauled away from the crematory to the dump. If the ash and cinders are both taken to the dump, instead of being brought to the crematory, one haul of the ashes and clinker is saved. This is worth not less than $1.00 per ton under favorable circumstances, which would be 70 cents per ton of cinders cremated. In consequence, this system contemplates spending 70 cents to secure fuel of steam-raising value equal to 13.6% of a ton of coal, which is equivalent to purchasing coal at $5.15 per ton.

(*d*) The above does not allow for the fact that the ashes will cost 10/3 as much as coal to stoke, or that, if wet, they will contain a large amount of water to be evaporated, which will make the price at which coal should be preferred still greater.

Moreover, the mixture of cinders with other refuse very greatly interferes with the most advantageous burning of refuse. Therefore it seems that the cinders and ashes should be collected and disposed of separately. By screening and otherwise carefully handling, it is possible that the combustible portion of ash-pan collections may be made to produce heat economically, but the problem should not be complicated by mixing ashes and refuse, or by attempting to reduce them in the same furnace, and the arguments for doing so usually presented are delusive. That there is no advantage in collecting them together has been pointed out elsewhere.

The preceding conclusions are theoretical, and lay no claim to extreme accuracy. They will be found sufficiently accurate to determine for any case, whether a consideration of a steam-raising proposition is worth attempting.

Data giving cost of incineration per ton for particular installations have been given by several writers in papers before various societies; but the writer of this, upon examination of such data, is convinced that except in a few rare instances the figures given are not correct, and, therefore, he refrains from quoting any of them. In some cases the costs appear very low, which is accounted for by the fact that the furnace discharges very offensive gases from the chimney, or disposes of the liquids without evaporation; in others, the charge to depreciation is unfairly small; in others still, those making the reports are interested parties, not strictly honest; and in yet other cases those who have collected data have been misled by inaccurate statements of their collaborators.

In general, however, it may be stated, that the cost of incinerating various wastes in plants now operating varies between the following extremes, interest, depreciation, and repairs being included. These costs do not take into consideration any steam-raising charges or credits.

Range of Costs of Incineration per Ton.

Garbage, 50 cts. to $2.50.
Cinders only, 20 cts. or more.
Refuse only, 25 cts. to $2.50.
Mixed garbage and refuse, 30 cts. to $2.50.

The highest figures are usually due to one of two causes, or to both:

(*a*) Operation of the incinerator only a short time each day or each week, because the quantity destroyed is very small.

(*b*) Frequent repairs made necessary by faulty construction or design, or by mismanagement.

In poor designs, auxiliary fuel sometimes amounts to 95 cts., or $1.00 per ton of garbage burned.

Accurate data of the amount of steam produced by burning refuse in the United States is not available. Many tests have been made in Great Britain, showing the amount of steam raised by burning such wastes, some of which will be discussed in the chapter on British Practice. The following two tables are taken from Mr. Goodrich's book, before referred to, though the data are available in original reports.

The second table is more useful for practical purposes than the first.

Those who may be inclined to study the heat available in any substance of known chemical composition are referred to Poole's excellent treatise entitled *The Calorific Power of Fuels* (Wiley & Sons). Table 1, "Heat of Combustion of Substances," Table 3, "Theoretical Flame Temperatures," and Table 13, "Quantity of Air Required for Perfect Combustion," are of special interest in this connection.

HEATING POWER OF ASH-PIT REFUSE. (DAWSON.)

The average heating power of the combustible portion of the refuse is as under:

	Calorific Value, or Units of Heat Developed per Lb. of Combustible.	
	When Dry.	When Containing the Average Percentage of Moisture.
Coal	14,000	9334
Coke	12,000	8000
Bones and offal	8000	5334
Breeze and cinder	6000	4000
Rags	5000	3334
Paper, straw, fibrous material, and vegetable refuse	3800	2534

AVERAGE EVAPORATIVE POWER OF TOWN'S REFUSE OBTAINED IN PRACTICE. (HUTTON.)

Description.	Weight of Water Evaporated from and at 212° F. Per Lb. of Refuse Fuel in Lbs.
Screened ash-pit refuse, the best.	2.00
Screened ash-pit refuse, averages	1.50
Unscreened ash-pit refuse, the best.	1.25
Unscreened ash-pit refuse, averages.	1.00
Unscreened ash-pit refuse of inferior quality seldom exceeds.	0.75
Unscreened ash-pit refuse, two parts mixed with street-sweepings, one part by weight.	0.75
Unscreened ash-pit refuse, two parts mixed with street-sludge, one part by weight.	0.50

Refuse described in above table yields on the average from 25% to 35% of clinker and ash.

CHAPTER VI.

CREMATORY-BUILDERS AND THEIR PRODUCTS.

The pioneer company in the installation of crematories in the United States, save for a few installations here and there of little practical importance, was the Engle Sanitary and Cremation Company with its principal office in *Des Moines, Iowa.* This company was incorporated in 1887, and purchased the patents of Andrew Engel, under which it constructed a number of crematories, some of which are still in operation. The principal stockholders were Mr. J. C. Savery and Mr. James Callahan. In 1894 Mr. Savery met with serious losses in other lines of business in which he was engaged, which caused the withdrawal of the working capital from the crematory concern. Mr. Savery died in 1905.

Between 1887 and 1894 the Engel Company built crematories at the following cities:

Des Moines, Iowa; Butte City, Mont.; Findlay, O.; Birmingham, Ala.; Jackson, Fla.; Tampa, Fla.; St. Augustine, Fla.; Panama, Colombia; Coney Island, N. Y.; 16th Street, N. Y., Board of Health; Savannah, Ga.; Richmond, Va.; Norfolk, Va.; Portland, Oregon; Milwaukee, Wis.; World's Fair, Chicago, 1893; Lowell, Mass.; Brunswick, Ga.

Smaller destructors were also put up for a number of private institutions.

The foregoing information was furnished to the writer from

FIG. 17.—Engle Crematory at the World's Columbian Exposition, Chicago.

FIG. 18.—Engle Crematory. View of Furnace.

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memory by Mr. Benjamin Boulger. This list of municipal plants may be incomplete.

In the employ of this Engel Company for several years were Mr. Benjamin Boulger and Col. W. F. Morse, to whom further references will be made in this chapter. Mr. Andrew Engel was not actively engaged in the business of the company. The original Engel patents expired in 1904.

The larger crematories of this make consisted of a combustion-chamber divided horizontally by a garbage-receiving platform made up of a series of brick arches, with slight spaces between them, through which the garbage might be stoked to the floor below, as it became dry, in combination with fire-grates for burning fuel. The furnaces were for the most part substantially built, and a number of them are still in daily use, though built more than twelve years ago. The illustrations afford a fair idea of the construction of these furnaces. These furnaces fall distinctly into Class 3, according to the nomenclature adopted by the writer in Chapter IV.

Next in interest in chronological order comes the Dixon Garbage Crematory Company which is still active in the business The following sketch and list of plants installed has been furnished by Mr. F. K. Rhines, Secretary and Chief Engineer of the Dixon Company, to whom the writer is further indebted for considerable of the information regarding miscellaneous plants given elsewhere in this chapter:

"Early in the last decade a company was formed at Findlay, Ohio, to exploit certain crematory patents granted to Samuel Dixon, of that city.

"Passing over the experimental apparatus set up there, the first municipal Dixon Crematory was installed at Elwood, Ind. This was quickly followed by other installations in the South and East, and, although the data regarding these early crema-

tories are rather meagre, it would appear that their performance was satisfactory, as the system was widely adopted, and, considering the lethargic state of city authorities at that period concerning questions of municipal sanitation, a remarkable number of plants were built in various parts of the country.

"After some five years the original Dixon Company, being insufficiently financed to handle the increasing business, was succeeded by the present company now controlling, at Toledo, Ohio, the original Dixon patents, as well as numerous others since granted on improvements and variations of the Dixon principle.

"As at first constructed, the Dixon furnace consisted of an elongated fire-brick chamber, encased in walls of common brick, with a horizontal burning-grate extending longitudinally from a double fire-box at one end to a fume cremator, or 'stench-fire,' at the opposite end; and this same form, modified and improved by being steel-jacketed and by the substitution of logical and more durable arches of fire-tile for the iron grates with which the destruction-chamber was originally fitted, is still used in some of the most modern and successful installations, and may be consideraed the representative type of American crematory.

"In the later patents taken out by the Dixon Company, the arrangements of grates and burning-chambers have been somewhat diversified, and many ingenious and important improvements made. Special crematories have been designed for the destruction of different classes of waste matter, and small furnaces adapted to institutional and private use. In all of the various forms of crematories now built under the name 'Dixon,' there is manifest a desire to adhere to the simplicity of principle which was the key to the success of the original invention.

"The work of the Dixon Company has extended from Boston to San Francisco, from the Great Lakes to the West Indies and the Gulf, and within the past few months two complete crematory

Fig. 19.—Salt Lake City's Dixon Crematory Plant.

plants have been built by this company for the city of Guayaquil, Ecuador.

"The fact that the Dixon Crematory has held first place in this country for over a dozen years, during which period a score of different furnaces have been experimented with by various cities and individuals, only to be abandoned, in most cases, after one or two trials, and that there are, at the present time, more Dixon Crematories in successful operation in the United States than of all other makes combined, cannot be passed over as insignificant to the earnest student of progress in this branch of sanitary science."

List of Dixon Crematory Plants.

Elwood, Ind.; Atlanta, Ga.; Camden, N. J.; Trenton, N. J.; Charlotte, N. C.; McKeesport, Pa.; Los Angeles, Calif.; New Orleans, La.; York, Pa.; Ft. Wayne, Ind.; Dayton, O.; Jacksonville, Fla.; Wilmington, Del.; San Diego, Calif.; Memphis, Tenn.; Youngstown, O.; Santiago, Cuba (U. S. Military Hospital); La Fayette, Ind.; Greenville, Miss.; Far Rockaway, N. Y.; Flushing, N. Y.; Long Island City, N. Y.; Jamaica, N. Y.; Port Richmond, N. Y.; Bridgeport, Ct.; West Point, N. Y. (U. S. Military Academy); Alexandria, La. (Parish Jail); Blackwell's Island, N. Y. (N. Y. Dept. Pub. Charities); Boston, Mass. (U. S. Army Post); Louisville, Ky.; Joliet, Ill.; Covington, Ky.; Cheyenne, Wyo. (U. S. Army Post); Portsmouth, Va. (U. S. Navy Yard); Mansfield, O.; San Francisco, Calif. (U. S. Army Post); Avalon, Calif. (U. S. Army Post); Philadelphia, Pa. (Reading Terminal Station); Hot Springs, Ark. (U. S. Army Post); Hamilton, O.; Wilmerding, Pa.; New Castle, Pa.; Allentown, Pa.; San Juan, Porto Rico (U. S. Army Post); Salt Lake City, Utah; Canton, O.; Dallas, Texas; Oakland, Calif.; Meadville, Pa.; Homestead, Pa.; St. Louis, Mo. (La. Purchase Exposition); Char-

leroi, Pa.; Wabash, Ind.; Canandaigua, N. Y. (F. F. Thompson Estate); Guayaquil, Ecuador, S. A.; Shreveport, La.; Lexington, Ky.

All of the crematories constructed by the Dixon Company have been of Class 3. In all later plants the plate-steel jacket gives the furnace a characteristic appearance, as shown in the illustration page 85. The variations in internal arrangement referred to by Mr. Rhines are largely methods of adapting the fires for furnaces of different lengths and methods of constructing stench-consumers. The practice followed has been to adopt a given typical cross-section for the furnace, and to extend the length a greater or a less distance to secure the capacity required for a given installation.

The patents owned by the Dixon Company are as follows:

No. 461,327, to Samuel W. Dixon, Oct. 13, 1891.

No. 517,816, to Samuel W. Dixon, April 3, 1894.

The drawings illustrating these show brick furnaces of Class 3, with "stench-bars" in the chimney, and flues for heating the air supplied for combustion. Later, Mr. Dixon took out patent No. 644,505 for a crematory with a conveyor located within it; but in this the Dixon Company is not interested, and the writer knows of no furnace built under its provisions.

No. 667,445, to E. J. Little, D. C. Shaw, and Geo. H. Breymann, Feb. 5, 1901. This applies to the most complicated of the Dixon furnaces,—those in which an extra drying-chamber is placed above the furnace proper. Means is provided for stoking garbage from the drying-chamber to the combustion-chamber. The air-heating flues in the original Dixon furnaces are omitted from the drawings in this case.

No. 724,898, to E. J. Little, G. H. Breymann, and D. C. Shaw, April 7, 1903. The drawings of this patent show the Dixon crematory enclosed in jacket of rolled steel, reinforced

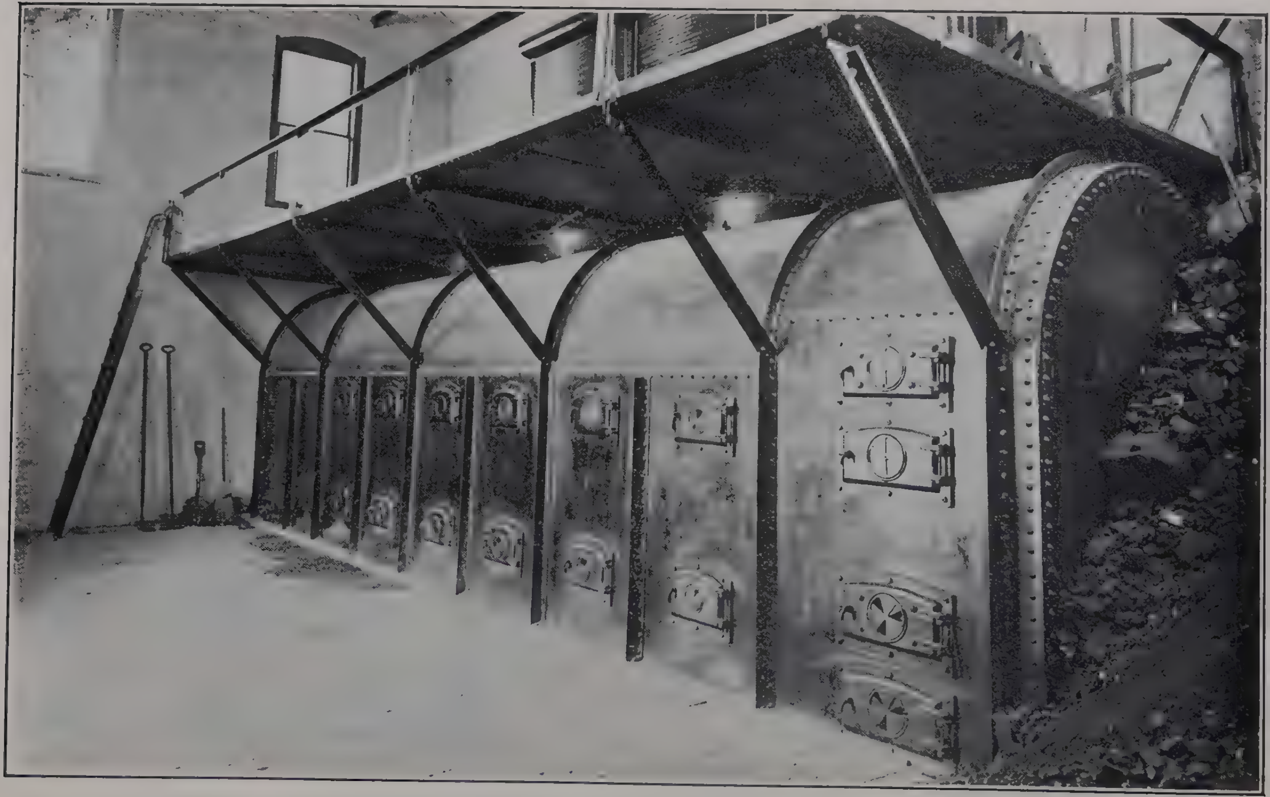

Fig. 20.—Exterior View of Dixon Furnace.

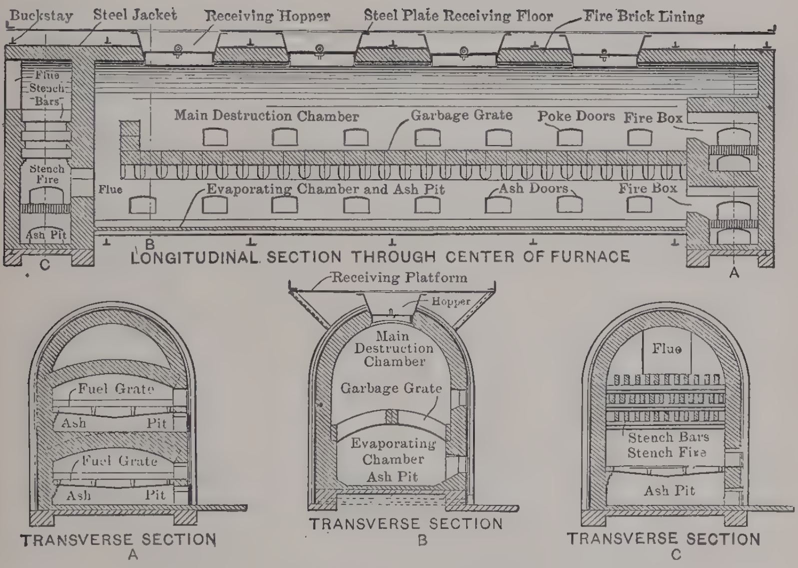

FIG. 21.—Sections of Dixon Garbage Crematory.

by "edgewise stiffening-plates,"—the construction typical of all later Dixon installations. The interior arrangement is an improvement on that shown in No. 667,445.

No. 789,329, to E. J. Little and D. C. Shaw, May 6, 1905. Fig. 11 illustrates this patent, which applies to the use of tubes of fire-clay heated to a high temperature from without, through which all gases of combustion must pass, and in which, it is claimed, they are heated so that odors are consumed.

There are usually to be found in every mechanical contrivance many features peculiar to the design of its manufacturer that are not patented, and may not be shown at all upon drawings intended to present special claims. Fig. 21 shows a Dixon crematory of a type of which a number have been built, and shows several of the features common to most Dixon furnaces. These features are:

1. An enclosing jacket of rolled sheet steel, built in sections, the sections joined together by angle-irons riveted to the sheets and stiffened by additional sheets clamped between the angles. This can make a very rigid jacket with a comparatively small amount of material. A strong jacket is an essential in this furnace to support the thrust of the fire-brick arches or grates within.

2. A lining of fire-brick, with fire-brick grates of peculiar pattern spanning the combustion-chamber throughout most of its length, and dividing it into two portions, one above the other.

3. "Stench-bars," located in the chimney, or in the path thereto.

4. One or two fuel-fires which pass their gases of combustion above and below the garbage-grates, and usually another fuel-fire immediately below the stench-bars.

The Decarie Manufacturing Company of Minneapolis came

into the crèmatory business about 1900, working under the patents of F. L. Decarie, formerly of Montreal, Canada, who is engineer for the company. The furnaces built by this company are the best known of those that employ water to cool the garbage-receiving grates. The furnace belongs to Class 4. The following description is extracted from a printed pamphlet describing a crematory built by this company at Atlanta, Ga., and sent to the writer in response to a request for an authorized description:

"The furnace walls are of steel, lined with a single course of fire-brick. . . . The crown is of steel plate, 18 inches high, and liberally stay-bolted. The upper grate-bars are joined directly to the crown, and connect it with the headers that extend along the lower part of each side of the furnace. The downward circulation of water is provided for by four 10-inch vertical wrought-iron pipes, that extend from the corners of the crown to the floor, having T-couplings with the headers, which are carried outside through the end walls of the furnace for the purpose. The vertical pipes also serve to keep the weight of the crown from the side walls.

"There are seven hoppers, all opening from the upper floor, to receive waste material. Four deliver direct to the upper grate. In these, mixed refuse and moderately dry garbage are dumped. One, built externally at the front, delivers dry combustible rubbish direct to the lower grate. Two are built externally at the sides of the furnaces, and in these very wet garbage is held, and allowed to drain its moisture into the evaporating-pan before delivering the solid material to the upper grate. The dumping is straight from the carts into the hoppers, and there is no handling of waste. The fire is hottest on the lower grate, where dry material is constantly burning. The gases of combustion pass through the material on the upper

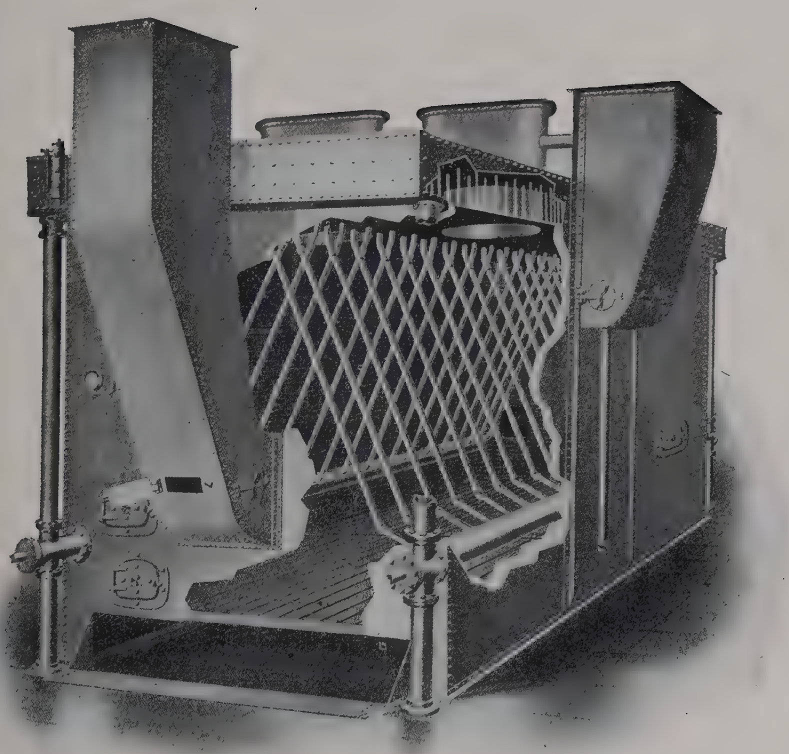

FIG. 22.—Construction of Decarie Furnace.

grate, and through a combustion-chamber at the back of the furnace, filled with brick checkerwork. Then they pass through two horizontal brick-lined flues about 8 ft. long, and are deflected downward from a height of about 10 feet to nearly the floor-level. Here they strike the surface of a water-tank, placed there to detain any particle of solid matter carried out of the furnace. They then pass between two coal-fires, which act as fume-consumers. The gases then pass over one baffle-wall and under another, getting a downward velocity a second time and striking a second water-tank. In the lower edge of the hanging baffle-wall is a perforated pipe, which projects a flat jet or curtain of steam downward. This steam carries into the water-tank any particles not previously caught. The gases then enter the stack, which is 200 feet high and 7 feet inside diameter.

"The material burned is mixed refuse, that is, kitchen garbage, rubbish, boxes, barrels, rags, paper, and, occasionally, a little manure. The bulk of the manure, night-soil, street-sweepings, and ashes are carted out of the city and disposed of in as sanitary and economical a way as may be."

Other plants built by this company are as follows:

Westmont, Montreal; Minneapolis, Minn.; The Bronx, New York; Johnstown, Pa.; Spokane, Wash.; Lowell, Mass.; Tampa, Fla.; Muncie, Ind.; Duluth, Minn.; Los Angeles, Cal.

As with the products of other companies, these furnaces have not all been of the same design, though they are alike in making use of steam-boiler tubes to support the refuse over a large grate, to which it is stoked by laborers as fast as it is dry enough to burn. Fig. 43, furnished by the manufacturers, illustrates the construction of the most recent furnaces.

These furnaces consist almost entirely of boiler-plate and tubes, the fire-brick linings on the Atlanta plant being only four and one-half inches thick.

The Decariè patents are as follows:

No. 596,421, Dec. 28, 1897 (reissue, No. 12,059).

No. 749,269, Jan. 12, 1904.

The arrangement of boiler-tubes actually adopted in the furnaces as built (shown in Fig. 43) more resembles that shown in the earlier patent than that shown in the later, which is illustrated in Fig. 13.

In the writer's estimation, this furnace is adapted for burning refuse not mixed with a considerable proportion of ashes, and containing not more than 25 to 40% of garbage by weight. When ashes or garbage predominates, the material sifts through between the boiler-tubes that form the upper grate, and falls upon the lower grate without preliminary drying. The company provides special receptacles for drying garbage, but the quantity that can be treated therein is small as compared with the quantity of refuse that can be consumed in the furnace proper.

Where no effort is to be made to utilize steam generated in the incinerator for power purposes, and the proportion of garbage is small, this incinerator is working under conditions most favorable for its success. But the location of the boiler between the principal fires and the material to be dried is unfavorable for power development, and the mechanical strains to which the tubes must be subjected by the weight of the garbage make it unsafe to carry very high steam-pressure; in fact, the arrangement is one very unfavorable to steam-generation for power purposes, where high and steady pressure are important.

The Municipal Engineering Company

was incorporated in Delaware on May 6, 1901, by Clarence S. Brown, N. C. Lyon, W. C. McFarland, and Fred P. Smith.

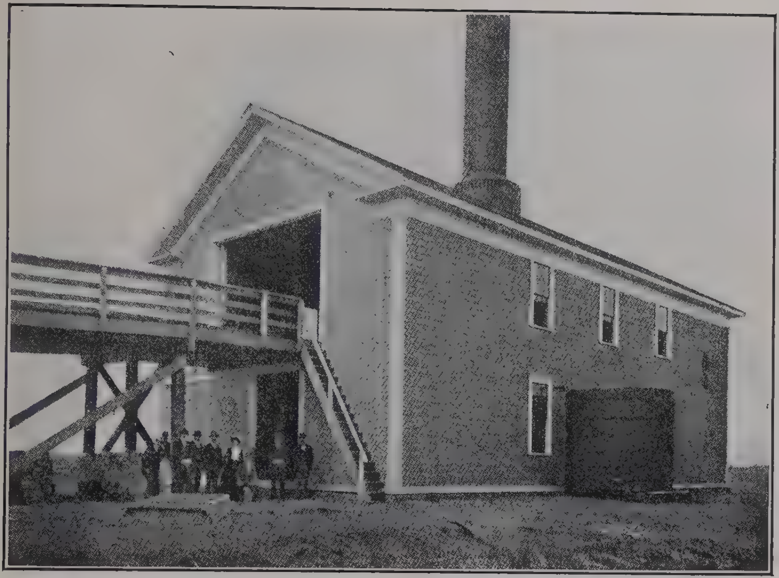

FIG. 23.—Decarie Crematory Building at Duluth, Minn.

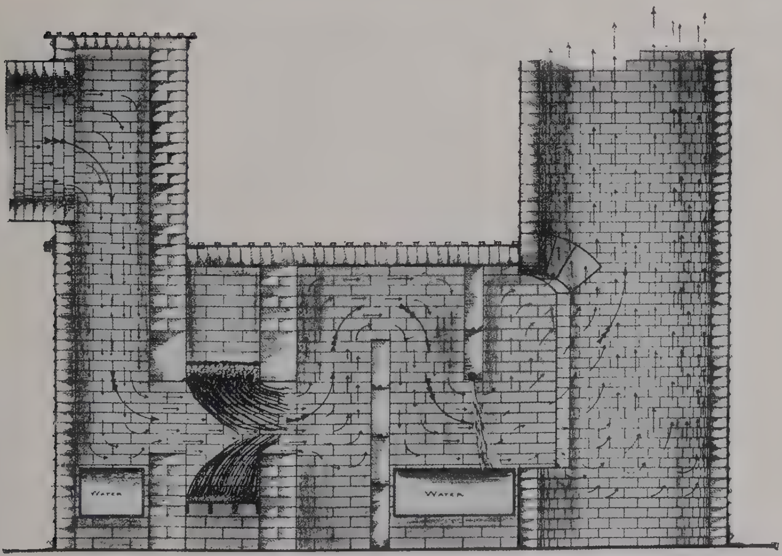

FIG. 24.—Stench-consumer, Decarie Furnace.

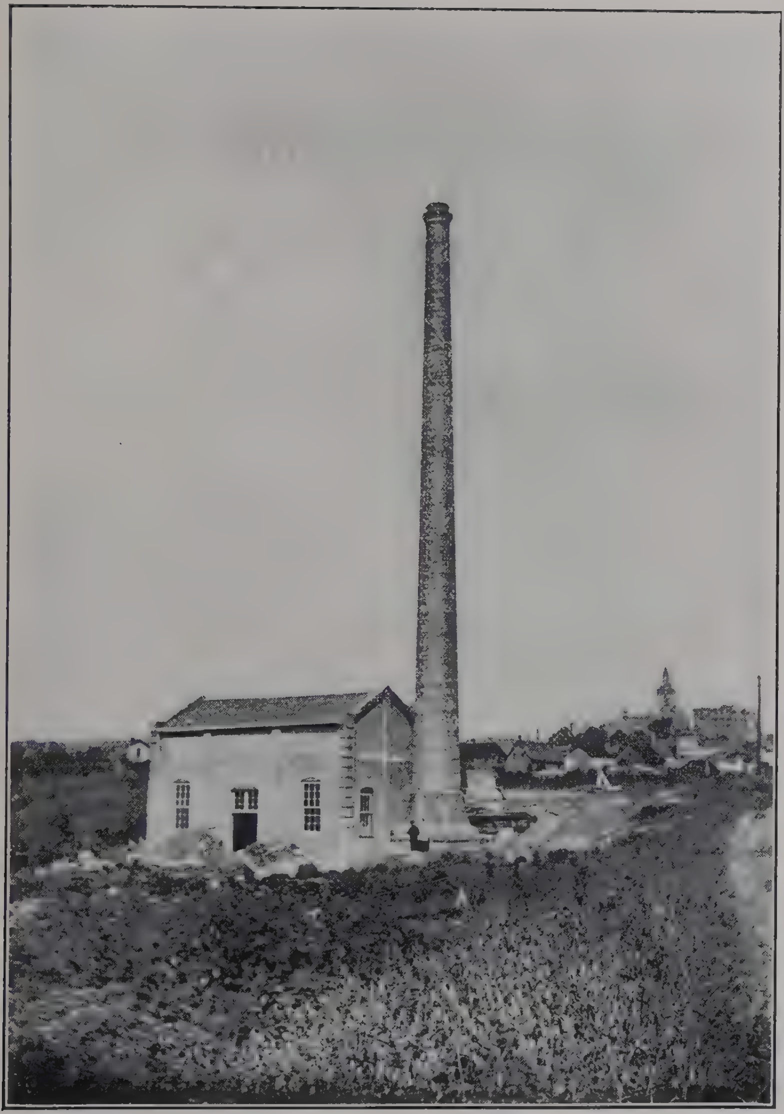

FIG. 25.—Crematory Building at Butler, Pa.
(Morse-Boulger System.)

Shortly thereafter Col. Willard Young became a stockholder and president. Captain McFarland and Col. Young financed the company and became the principal stockholders, eventually acquiring all the stock in 1904. In that year Mr. Smith's connection with the company ceased. In October, 1904, the company sold its patents and goodwill to The Sanitary Engineering Company, an account of which will be given later. This company is continuing the business with modified and improved types.

Mr. Benjamin Boulger and Col. W. F. Morse,

after leaving the Engel Sanitary and Cremation Company, engaged in business together. They designed and supervised the Boston refuse-destructor (30 tons daily capacity), and designed a plant erected by the United States Government at Manila, P. I. (130 tons daily capacity). They also built plants at the following places:

San Salvador, 40 tons; Kings County (Brooklyn), 10 tons; League Island, 10 tons; Sailors' Snug Harbor, L. I., 8 tons; Bellevue Hospital, and about 20 other private institutions requiring small furnaces only.

In 1902 the Morse-Boulger Destructor Company was originated to secure more capital upon which to work. Mr. Boulger furnished the following list of the more important installations since the incorporation. Of this company Mr. Boulger now owns the controlling interest, Col. Morse having withdrawn from active participation in the business:

Belmont Hotel, 41st St. and Park Ave.; Siegel's Store, Boston; New York Navy Yard; St. Francis Hospital, 142d St. and Brook Ave.; Butler Pa., City; Cammeyer Library; Ft. Logan, Colo., U. S. Army Post; Randall's Island, Dept. Charities, New York City, Ear, Eye, and Throat Hospital, New York;

Mexico Hospital, Mexico City; German Hospital, 76th St. and Park Ave.; Jefferson Medical College, Philadelphia, Pa.

Fig. 10 shows the general type of furnace built by this company.

Next to the Dixon, this crematory is perhaps the best-known in America. In one sense, it is the lineal descendant of the Engel Crematory, Mr. Boulger having been the constructor of many of the Engel furnaces, and Col. Morse having been the commercial representative of that concern. In exterior appearance the Morse-Boulger furnace resembles the Engel, being a substantial brick structure stayed with heavy buckstays. In internal arrangement, however, it is a considerable departure.

Mr. Boulger's two patents are:

No. 537,181, dated April 9, 1895, and
No. 773,920, dated Nov. 1, 1904.

The later crematories all resemble in design the drawing shown in Fig. 10. A large surface of garbage is exposed to the heat of the principal fire by making the roasting hearth double—one hearth above another, each formed of arches of fire-brick with small spaces between. The main fire may be either of fuel or of refuse, if the latter be sufficiently combustible. The stench-fire must be of fuel. The broken brickwork in the passage to the stack serves as an extra stench-consumer, and also arrests any light refuse or paper that may be carried that far by the draft within the furnace.

This furnace must be classed partly in Class 3 and partly in Class 2, in that when there is sufficient refuse to burn without other fuel, it is used on the principal fire; but the garbage, or swill, is consumed on the fire-clay grates. The furnace may be equipped readily with forced draft.

This crematory is working at its best when consuming a considerably larger quantity of garbage than of refuse, but yet is

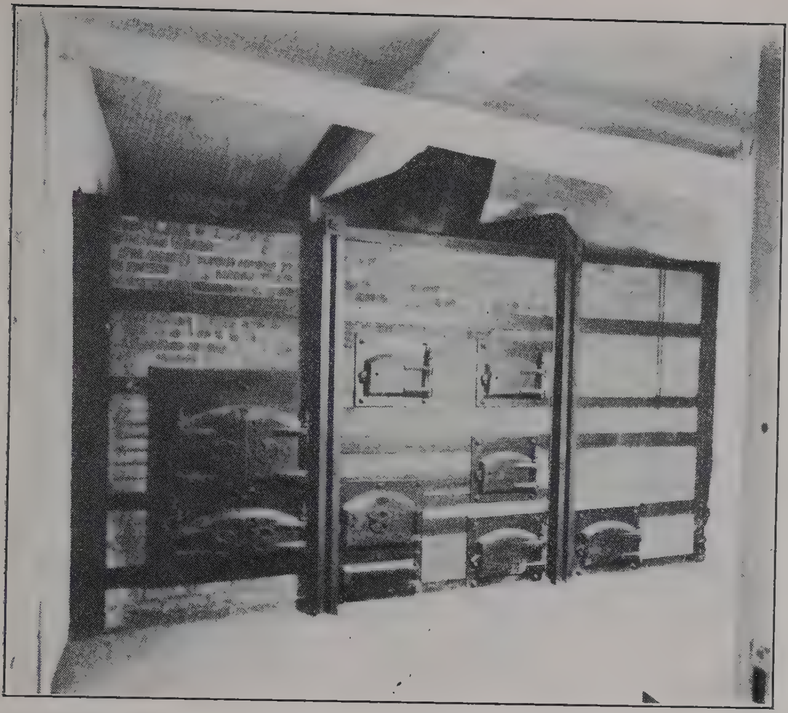

Fig. 26.—Exterior of Small Boulger Furnace.

Fig. 27.—Building of "Sanitary" Crematory at Fort McKinley, Maine.

supplied with sufficient refuse, separately collected, to maintain the fire on the principal grate.

The Morse-Boulger Destructor Company also represented the Meldrum Bros., Ltd., of England; but when Colonel Morse withdrew from active participation in the Morse-Boulger Company he retained the representation of the firm. He has since constructed a Meldrum destructor at Westmont, near Montreal.

Sanitary Engineering Company, incorporated in New York in 1904, purchased and continued the business of the Municipal Engineering Company of Delaware. The principal stockholders are Captain Wm. C. McFarland, Colonel Willard Young, Mr. Franklin Nevius, and Captain Wm. M. Venable. The crematories are of Class 4, as designated in Chapter IV, using air to cool the garbage-grates.

The following are the crematories built by this company and its predecessor:

Long Branch, N. J.; Fort Moultrie, S. C. (U. S. Army Post); Fort Brady, Mich. (U. S. Army Post); Long Beach, N. Y. (Hotel); Fort Slocum, N. Y. (U. S. Army Post); Fort Leavenworth, Kan. (U. S. Army Post); Governors Island, N. Y. (U. S. Army Post); Fort Meyer, Va. (U. S. Army Post); Fort McKinley, Maine (U. S. Army Post); Fort Riley, Kan. (U. S. Army Post); Fort Barrancas, Fla. (U. S. Army Post).

The patents owned by this company relating to crematories are as follows:

$$\left.\begin{array}{r}766{,}848\\766{,}849\\783{,}473\\783{,}475\\783{,}476\\800{,}177\end{array}\right\}\text{ to Fred P. Smith.}$$

Other applications of the writer are allowed. These

patents cover various constructions intended to effect the cooling of garbage-receiving platforms by circulating air through them, and the subsequent use of that air within the furnace, and other matters. Fig. 14 illustrates the general type of furnace built by the Municipal Engineering Company, though later furnaces departed from this plan. The general design of the Sanitary Engineering Company is shown in Fig. 28. The company builds two styles: Type J, which is enclosed in a reinforced concrete jacket, and Type H, which is enclosed in a jacket of cast-iron panels. The arrangement of the interior of the furnace is similar in the two types.

The garbage is received into the furnace on a floor of bars, composed of hollow prismatic castings, one fitting over the other so as to allow air to pass between the two. Some distance below these are arranged a series of burning grates. Air is drawn into the ash-pits of these burning-grates, after previously passing through the hollow bars above, where it keeps the bars from burning out, and at the same time becomes heated before being supplied to the fires. The hollow bars may be rotated from without the furnace to feed dried garbage or refuse to the grates below, and the draft for each section of burning grate is subject to control. Variations of the design are made to meet particular cases, and to adapt it to small installations as well as to large ones; but the central ideas of heating the air supplied for burning, and of cooling the receiving platform by the same air, is carried out in all the later designs. These crematories are of Class 4.

The builders named in the foregoing have installed most of the crematories in the United States. But there are many other installations by various builders that will here receive a briefer notice, chiefly because only a few of each type have been installed, so far as the writer has been able to learn.

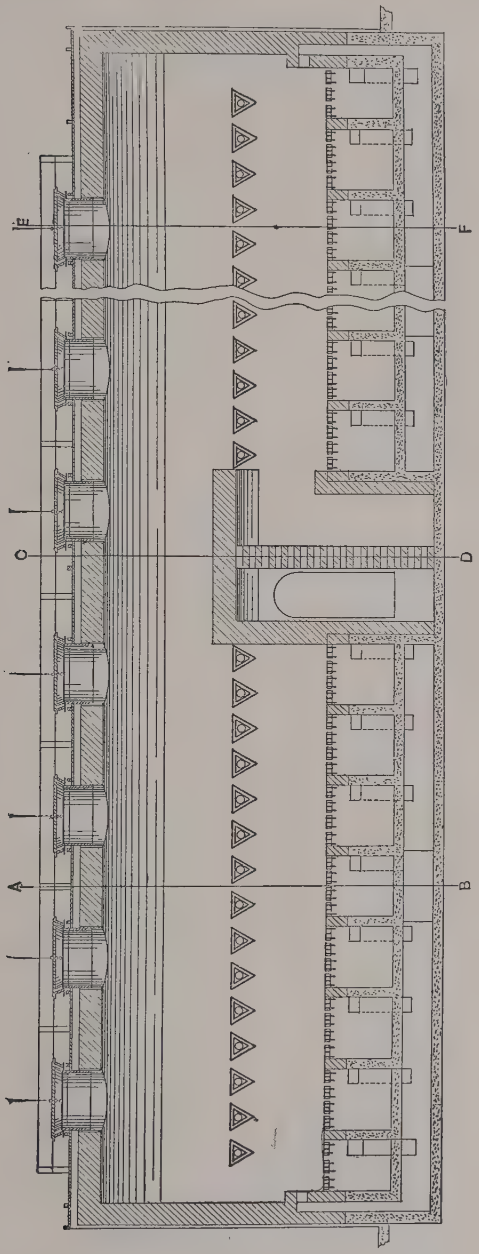

Fig. 28.—"Sanitary" Crematory, Type "H".

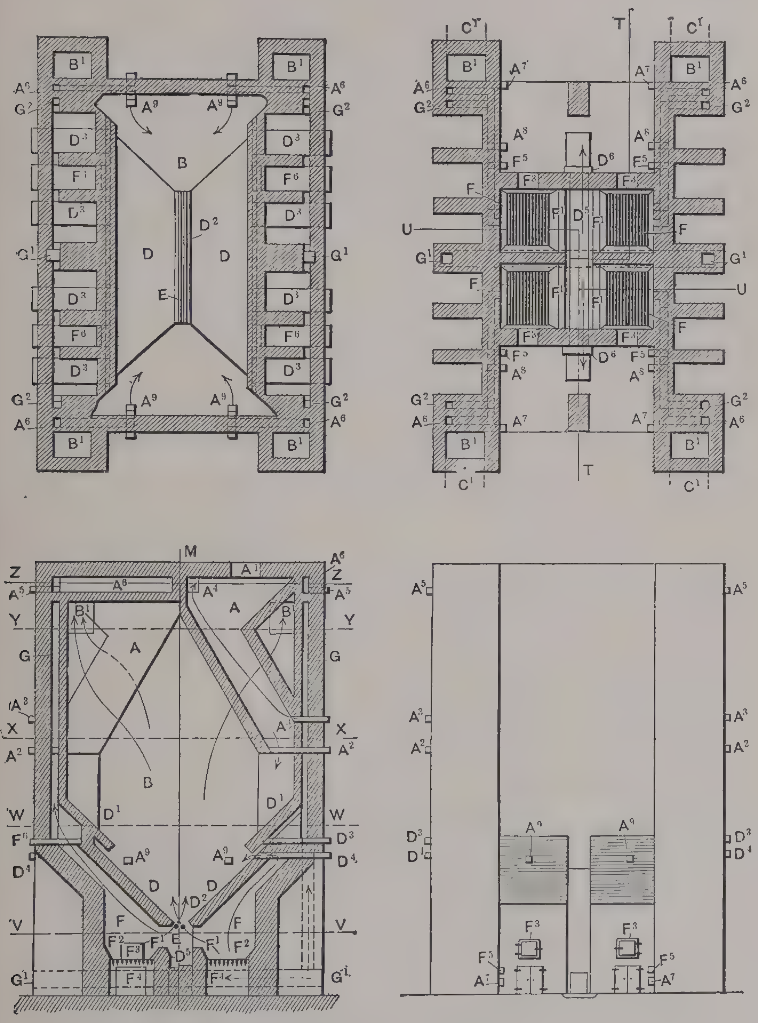

FIG. 29.—Vivarttas Cremating Furnace.

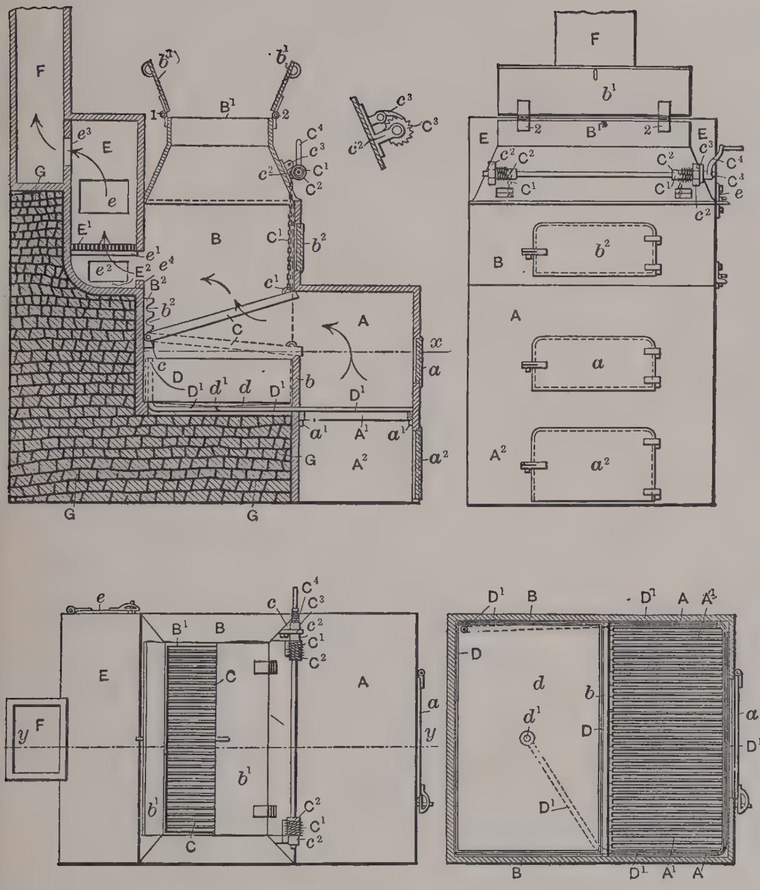

FIG. 30.—Davis Garbage Furnace.

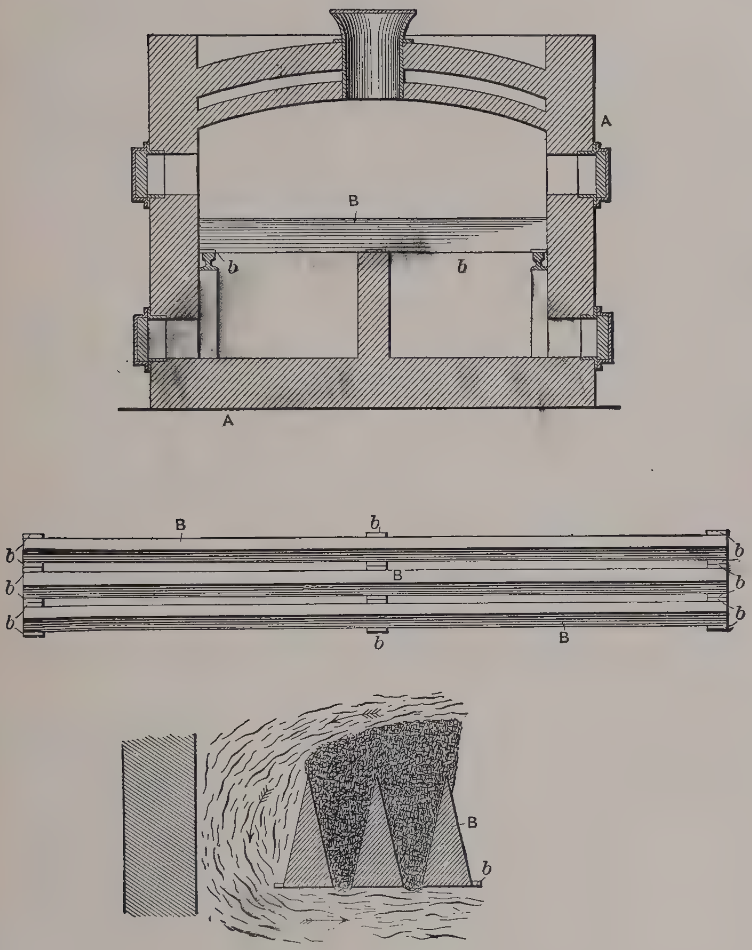

FIG. 31.—Brown Crematory Grate Bar.

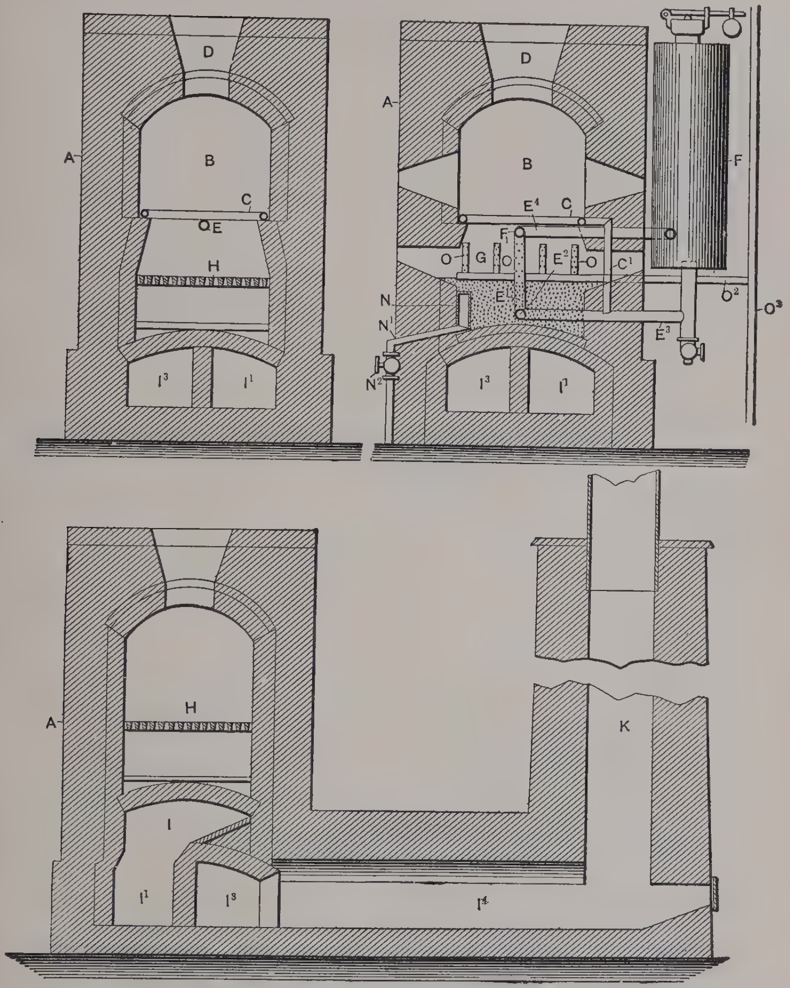

FIG. 32.—Brownlee Garbage Furnace.

1. The "*Smith Vivarttas*" crematories, at Scranton, Pa., and Plainfield, N. J., are not easily illustrated because the complication of passages cannot be shown in a single drawing. Fig. 29 gives some idea of this complication. The object sought is to heat air on its way to the fires by placing air-passages adjoining flues for burnt gases. The patent number is 390,922, to A. Vivarttas, dated Oct. 9, 1888. It has therefore expired. No recent installations are known.

2. The "*Davis*" crematory is illustrated by Fig. 30, taken from patent No. 462,035, Oct. 27, 1891. Crematories of this type have been built at Oil City, Pa., Trenton, N. J., and Regla (near Havana), Cuba. No recent installations are known. The plants built depart somewhat from the construction shown in the patent.

3. The "*Anderson*" crematory, at Chicago, was made by converting a brick-drying oven at Chicago. It is covered by patent No. 526,283, Sept. 18, 1894.

4. The "*McKay*" crematory is illustrated by Fig. 12, taken from patent No. 530,623. One furnace of this type was built at Yonkers, N. Y., where it is still in service, though frequent replacing of the garbage-grates is necessary.

5. The "*Brown*" crematories, at Boston, Mass., Wilmington, Del., and Washington, D. C., are covered by patents No. 501,181, 537,801, and 644,966. They belong to Class 3. Patent No. 644,966 is of interest as representing the only patented attempt to make a solid cast-iron garbage-grate, exposed to fire on its underside, resist the furnace temperature because of its peculiar form. It is shown in Fig. 31.

6. The "*Brownlee*" crematories are covered by patents No. 448,115 and No. 537,339. They belong to Class 3. Mr. Brownlee was at one time agent for the Engel Sanitary and Cremation Company, in Texas. Brownlee crematories were

built at Jamestown, Texas, and Terre Haute, Ind. Fig. 16 illustrates one of the two patents. There are no recent installations.

7. The "*Thackeray*" incinerators at Montreal and San Francisco have been described frequently as examples of the British type in America. The Thackeray patents are No. 553,574 and No. 644,980. Fig. 33 illustrates one of these. No plants have been erected recently.

8. The "*McGeihan*" incinerator at Syracuse, N. Y., is probably the only furnace in America employing a rotating kiln to dry the garbage. The patents of McGeihan are No. 554,453 and No. 562,845. Illustration is found in Fig. 18.

9. The "*Wright*" incinerators at Chicago are of Class 2. Patent No. 575,088, applying to them, is illustrated in 4.

10. The "*De La Chapelle & Pearce*" crematories, covered by patent No. 577,184, dated Feb. 16, 1897, are illustrated in Fig. 35. Representatives of this furnace were erected at Evanston and Ottawa, Ill.

11. The "*Stringfellow*" furnace, at Findlay, O., is illustrated by Fig. 36, taken from patent No. 583,663, granted June 1, 1897. The furnace is of Class 3, and employs a garbage-grate of pipes kept cool by water circulated through them.

12. The "*Walker*" patents, No. 584,434 and No. 719,946, show the arrangement illustrated in Fig. 15. The licensee under these patents, Mr. Geo. H. Pierson, has designed furnaces erected at McKeesport, Pa., Charlestown, W. Va., and Marion, O. These differ materially from the arrangement shown in the Walker patent, especially in the arrangement of dampers, but the feature of reversing the draft is retained. These furnaces belong to Classes 3 and 5.

13. "*Smead's*" patents, No. 607,553 and No. 691,378, utilize

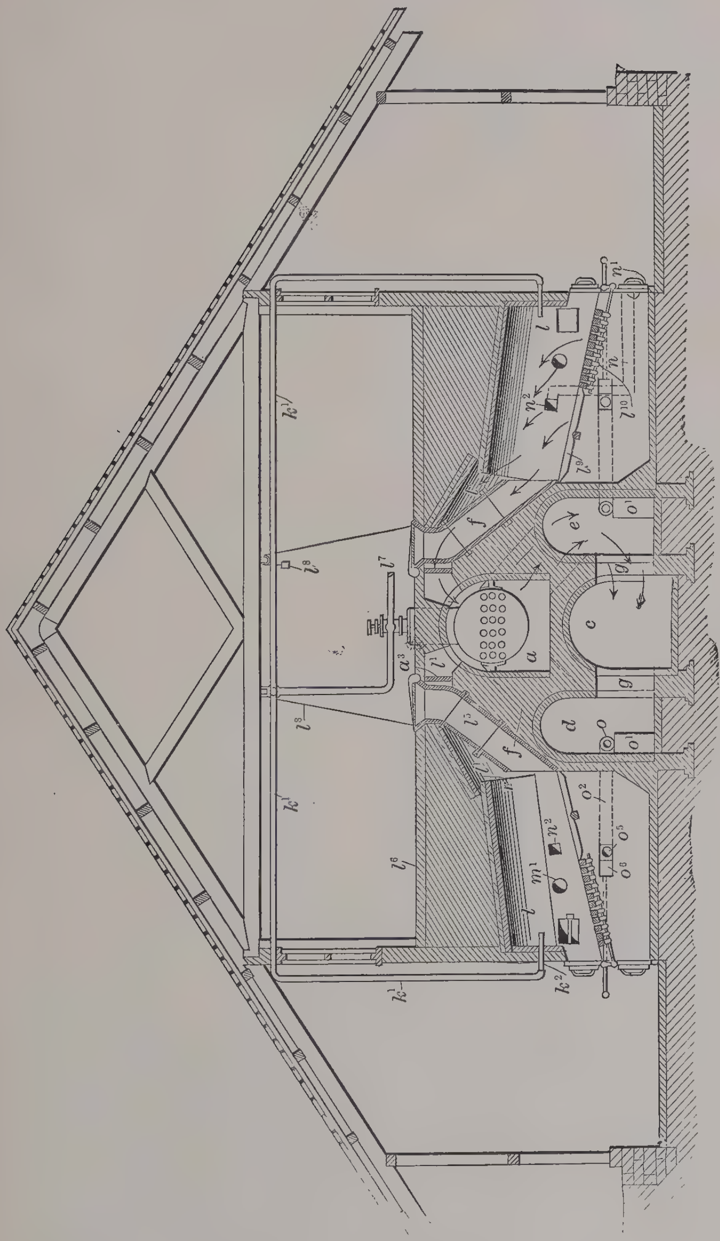

FIG. 33.—Thackeray Incinerator.

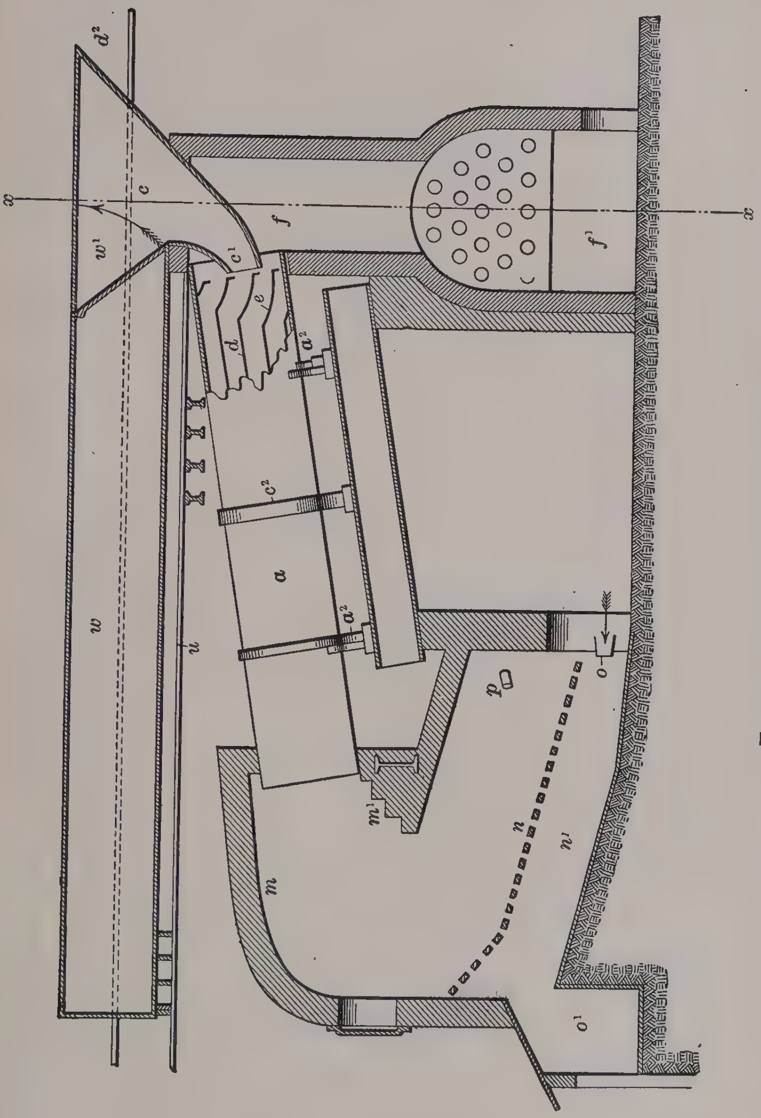

FIG. 34.—McGiehan Refuse Burner.

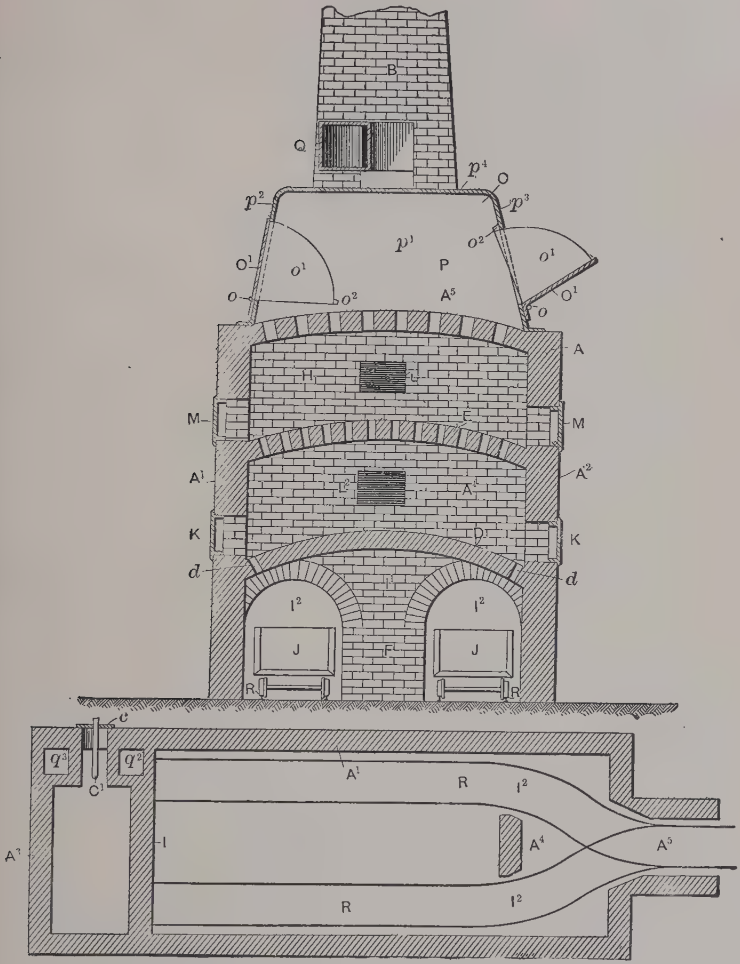

FIG. 35.—De La Chapelle & Pearce Garbage Furnace.

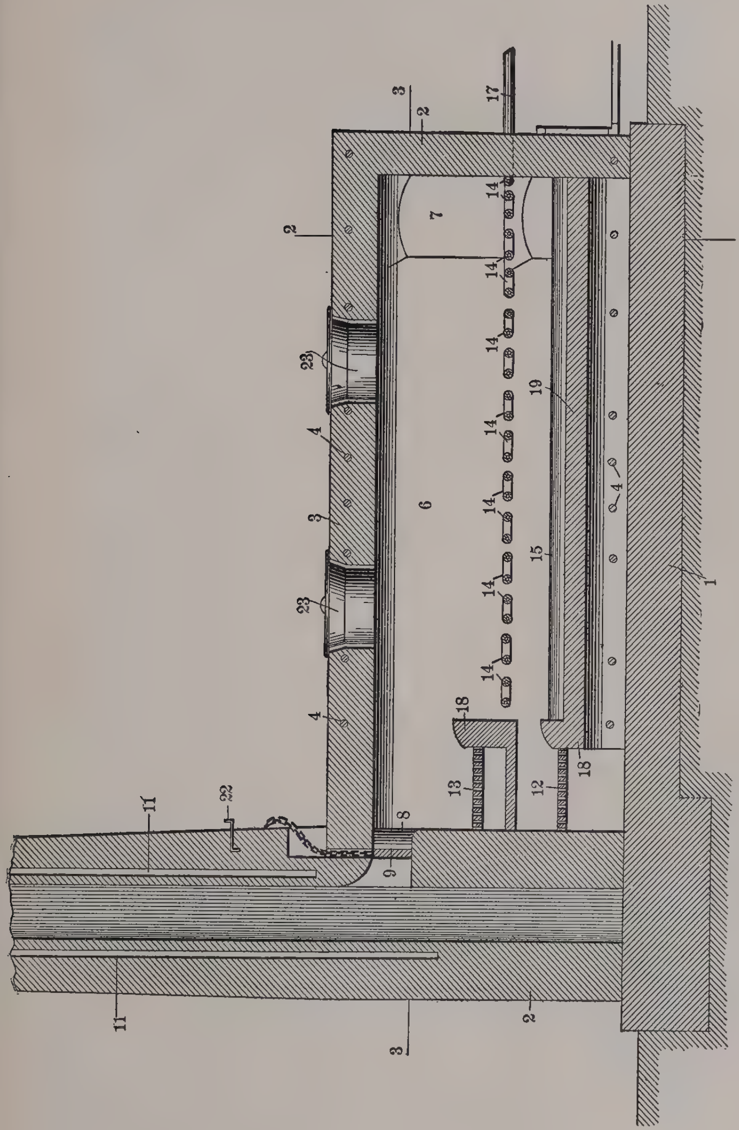

FIG. 36.—Stringfellow Garbage Furnace.

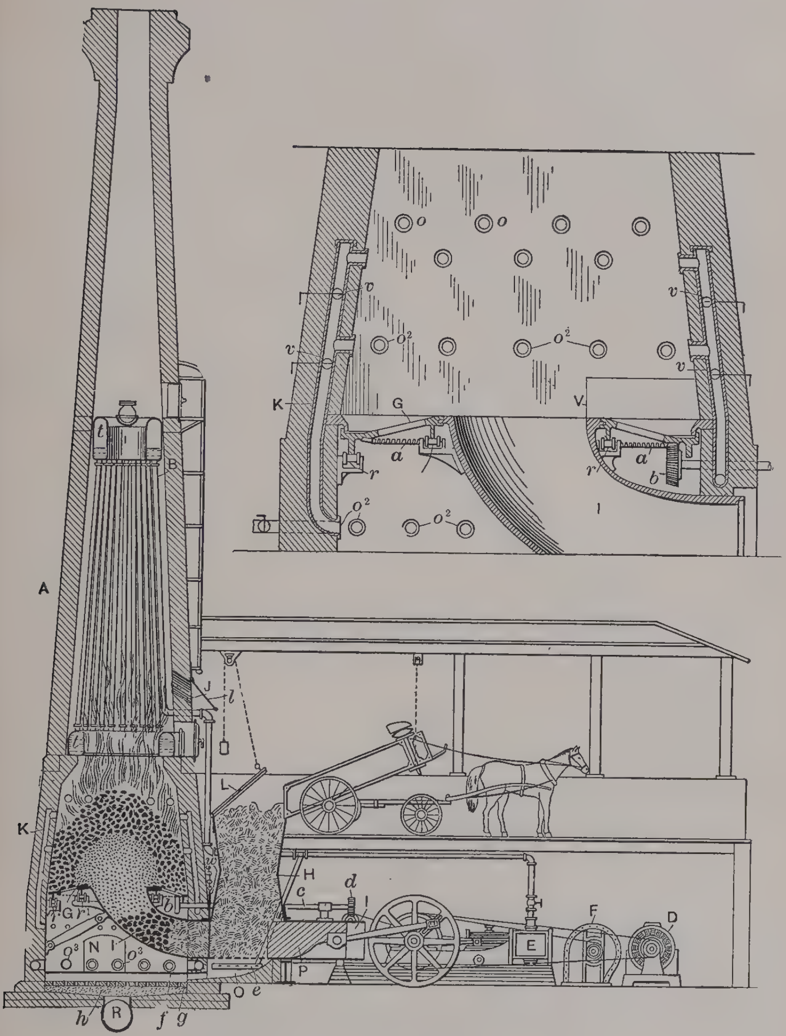

FIG. 37.—Smead Garbage Furnace.

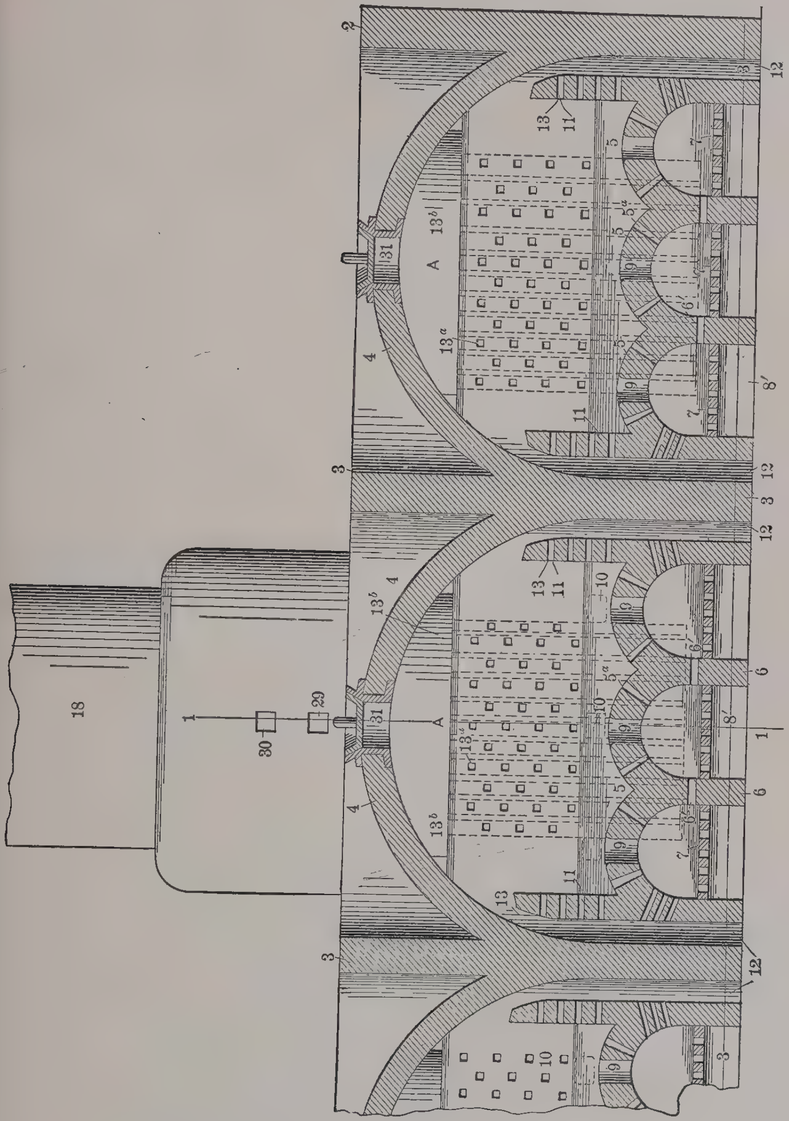

FIG. 38.—Lester & Dean Furnace.

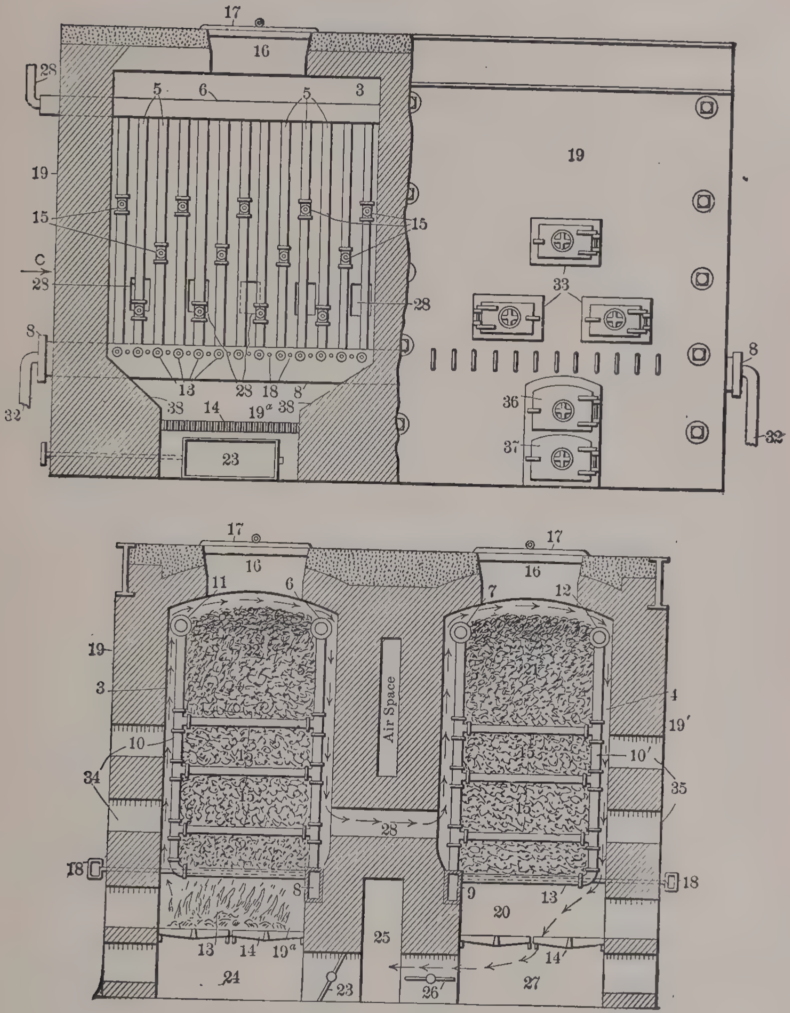

FIG. 39.—H. B. Smith Garbage Crematory.

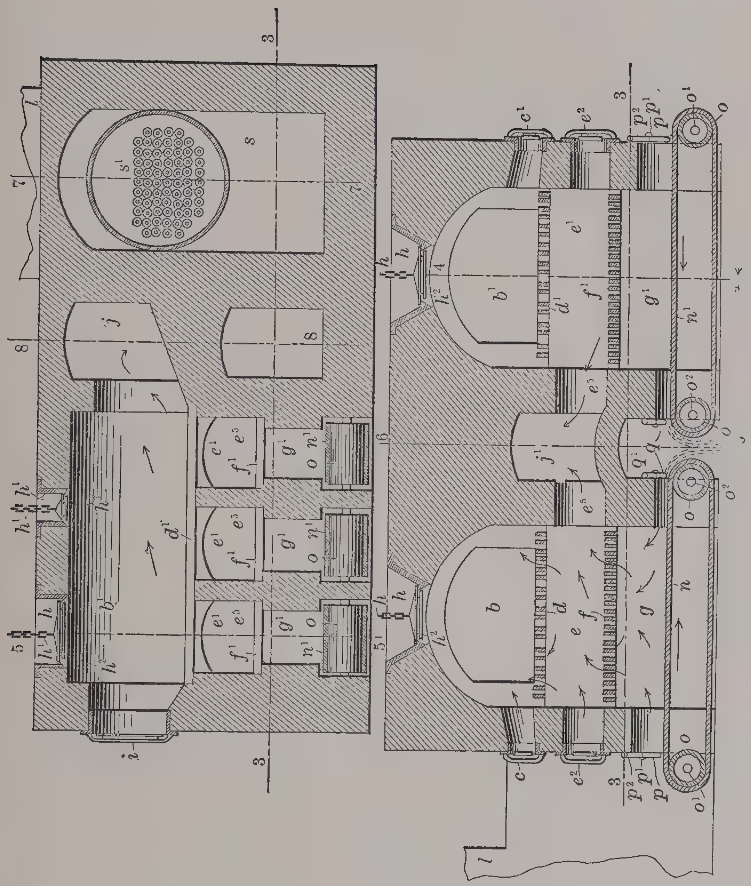

FIG. 40.—Stearns Incinerating Furnace.

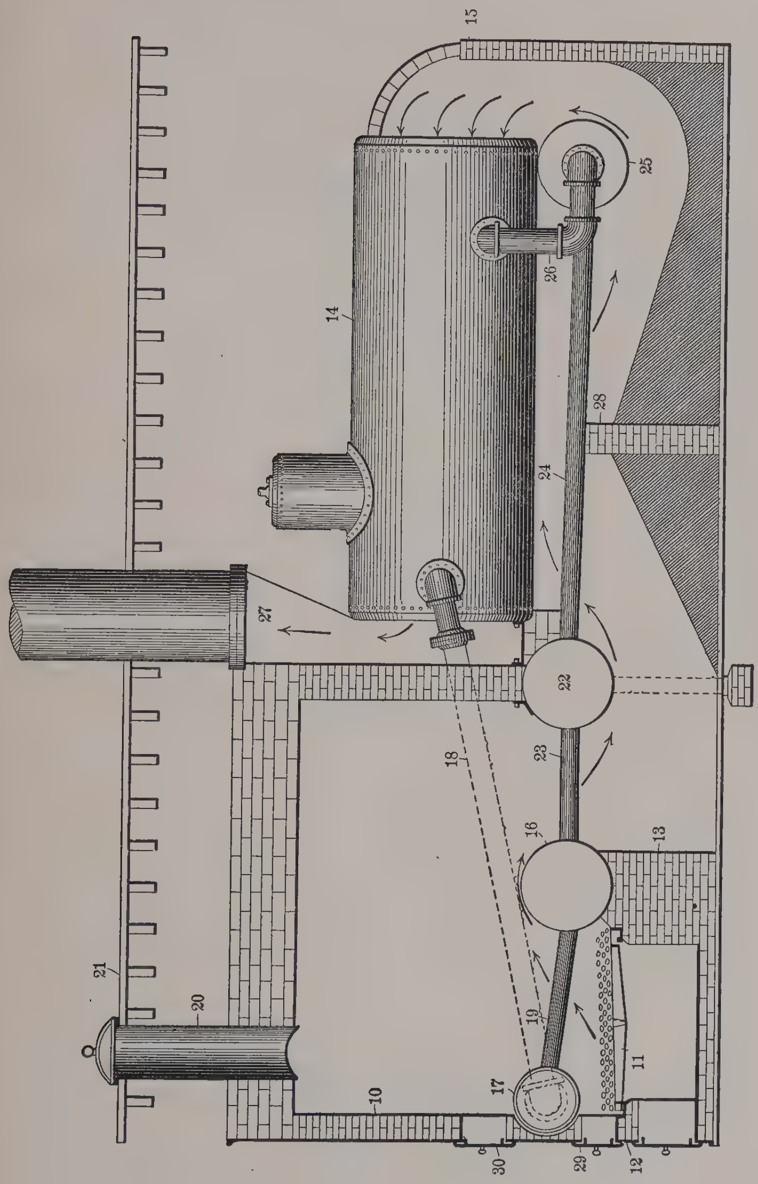

FIG. 41.—Wiselogel Refuse Burner.

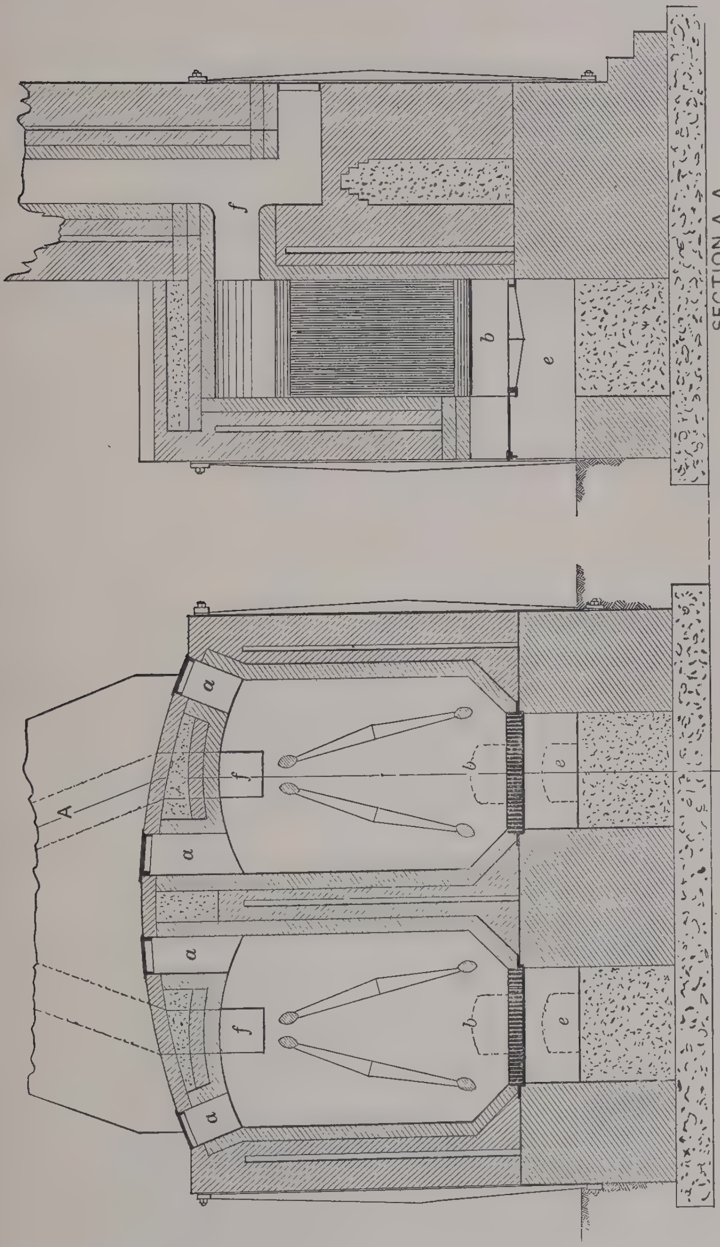

FIG. 42.—"U. S. Army" Garbage Crematory.

a grate revolving on a vertical axis, shown in Fig. 37. A furnace built by Smead & Company is reported at Toledo, O.

14. The "*Lester & Dean*" furnace at Atlanta, Ga., is illustrated in Fig. 38, taken from patent No. 658,658. Mr. L. A. Dean also took out patent No. 675,884. It belongs to Class 4.

15. The "*H. B. Smith*" crematory is illustrated in Fig. 39, by the drawing from patent No. 757,149, issued April 12, 1904. Crematories are reported to have been erected under this patent at Waterbury, Conn., Scranton, Pa., and Newport News, Va. It belongs to Class 4.

16. The "*Stearns*" refuse-destructor was erected in New York. Patent No. 772, 681, issued Oct, 18, 1904, applying to it is illustrated in Fig. 40, but a single sheet of these patent drawings cannot convey a very clear idea of the arrangement.

17. The "*Wiselogel,*" patent No. 803,650, is shown in Fig. 41. It belongs to Class 4. A furnace under this patent has recently been installed at Jacksonville, Fla., in connection with a reduction plant.

Besides these types listed above the following installations are reported, regarding which the writer has not sufficient data to make even a short description.

18. The "*Smith Siemans*" furnaces at Muncie, Ind., and Atlantic City, N. J.

19. The "*Rider*" furnaces at Allegheny and Pittsburg, Pa.

20. The "*Burns*" incinerator in Brooklyn, N. Y.

The refuse-destructor, designed by Mr. Parsons for the 34th Street refuse-sorting station, is referred to elsewhere in this book.

Of the plants instanced in the foregoing many are now out of service or abandoned. The names are arranged in order of dates of the patents issued.

21. "*U. S. Army*" crematories (Fig. 42) at various army posts. None operating now.

CHAPTER VII.

BRITISH PRACTICE, AND BURNING REFUSE FOR STEAM PRODUCTION.

If the collection of garbage, refuse, and ashes in a single receptacle and their destruction in one furnace can be shown to be more sanitary and more economical than separate collection and disposal, it must be admitted that British destructors are in advance of American crematories on the road to the final solution of the problem of refuse disposal; but if the separate system of collection is to be adopted finally in America, it may well be doubted whether destructors of British type will ever come into extensive use here. For in the design of crematories to burn garbage only we are certainly ahead of Great Britain; and American plants for disposing of refuse, unmixed with ashes, cannot be pronounced generally inferior to the British plants for burning mixed wastes.

The writer has elsewhere expressed the opinion that separate collection of garbage, refuse, and ashes is preferable, from every point of view, whether the final disposition is to be burning of all or only a part of them; that the garbage can be more economically burned in one furnace, the refuse in another, and the cinders in another, provided the quantities are large; and that the problem of the economy of reburning cinders should be considered on its own merits, without being joined to that of destroying other refuse.

In America, at present, the reburning of cinders to recover

the heat not developed on first burning of coal is not likely to meet with general adoption, and the problem to be determined by most municipalities is not, shall there be two systems of collection, but shall there be three.

The refuse-destructors in the United States, where refuse is sorted on a large scale and only the worthless burned, are fed with refuse that contains no garbage and no cinders, or only very small amounts of either, accidentally or carelessly introduced, and they are no more to be likened to British destructors than are our crematories for garbage only.

American crematories are intended primarily to destroy the kitchen garbage and swill, and though they also burn refuse, they seldom also undertake to reburn ashes and cinders. Garbage and refuse are often brought to them in separate carts, and not mixed until dumped into the furnaces, separate parts of the furnaces being not infrequently used for each.

Bearing these conditions and practices in mind, we may study British methods with profit without being likely to misapply conclusions of British authors and builders, but still willing to adopt their methods of a common system of collection and disposal of all kinds of wastes wherever it can be shown to be advantageous.

We are indebted to Mr. W. F. Goodrich, A. I. Mech. E., for the most available information on refuse destruction in Great Britain, Mr. Goodrich having written two books on this subject. In America, Col. W. F. Morse has written many magazine articles on this problem. It should also be noted that Mr. Goodrich is the author of several publications distributed as trade literature by Meldrum Bros., Ltd., one of the largest builders of refuse-destructors in Great Britain, and that Col.Morse has been for many years the American representative of the same company. Meldrum Bros. control the "Meldrum" and the "Bea-

man and Deas" patents. To one who is obliged to form an idea of the relative importance of British destructor companies by reading technical journals, it appears that Meldrum Bros. and The Horsfall Destructor Company (of Leeds) are the leaders, though several other companies have put up very creditable plants. A list of British destructors patented in the United States will be found on page **146.**

The following data, taken from a circular of Meldrum Bros., and relating to tests of a destructor installed by them at Nelson, Lancashire, are of interest as representing the best results in steam raising that can be hoped for under good conditions in Great Britain:

"**Mean Temperatures.**—The estimated mean temperatures on the two days were 2634 and 3326 degrees F. and nickel, melting at 2640 degrees F., was fused when held in the flame. . . .

"**Quality of Refuse.**—The refuse consumed at Nelson was taken from exposed ash-pits, and consisted principally of cinders and kitchen refuse; offal from the slaughter-houses was also burnt in this destructor, but in view of the nature of this fuel being totally different from that burnt during the rest of the time, it was considered advisable not to complicate matters by burning this offal during the test. It may here be mentioned that refuse of this nature is shot into the extreme end of the combustion-chamber, so that noxious gases which would be generated have to pass over four furnaces, whose fuel is on such occasions purposely well burnt through. . . .

"**Date of Tests.**—The trials were carried out on Tuesday and Wednesday, the 13th and 14th January, 1903. The refuse was weighed on entering the premises. A sufficient quantity to last for nearly three hours' run was tipped into the bin and was burnt up before the next lot was tipped. The two days' trial, therefore, consisted of a series of six short ones which could be compared amongst themselves."

TABLE I.

	Tuesday.	Wednesday.
Dates of trial	13–1–03	14–1–03
Time of trial	10—5.45	9.35—6.35
Duration of trials, hours	7.75	9.00
Boiler pressure mean, lbs	135.1	134.2
Corresponding temperature, degrees F.	358.2	357.8
Refuse burnt during trial, lbs.	45,416	43,400
Refuse burnt per hour, lbs.	5,837	4,822
Feed-water supply during trial, lbs.	63,723	67,485
" per hour, lbs	8,191	7,498
" per lb. of fuel, lbs.	1.419	1.555
Moisture in steam, per cent	1.07	1.034
Temperature of feed, degrees F.	37.3	35.3
Evaporation per lb. of fuel from and at 212° F., including steam-jets, lbs.	1.698	1.877

TABLE II.

MEAN CORRECTED GAS ANALYSIS (VOLUMETRIC).

	Atmosphere.	Tuesday.	Wednesday.
Nitrogen, N_2.	79.080%	79.525%	79.888%
Oxygen, O_2.	20.880	8.140	5.836
Carbonic acid, CO_2.	.040	12.205	14.233
Carbon monoxide.	....	.130	.043
Total.	100.000	100.000	100.000

OTHER ANALYSES.

	Tuesday.	Wednesday.
Carbon in ashes, etc., %.	11.44	17.69
Mean ratio of moisture to CO_2 in waste gases.	.7549	.5479
Estimated steam (jets) per lb. of refuse.	16.22	18.70

COMPOSITION OF FUEL CALCULATED FROM ABOVE DATA.

	Tuesday.	Wednesday.
Carbon (burnt).	21.33%	31.58%
Carbon (in ashes).	4.17	5.70
Total carbon in fuel.	25.50	37.28
Moisture.	35.00	30.53
Mineral matter.	39.18	31.50
Total refuse.	100.00	100.00
Additional steam by jets.	16.22	18.70
Air, including moisture.	422.73	542.46
Total.	538.95	661.16
Less ashes, etc., in furnace and flues.	43.35	37.16
Difference being weight of waste products per 100 lbs. refuse.	495.60	624.00

ESTIMATED CALORIFIC VALUE OF FUEL.

Calorific value of total fuel, B.T.U	3473	5411
" " " " " evaporated units	35.95	5.601
Ditto less unburnt carbon, B.T.U	2867	4582

FURNACE TEMPERATURES.

Heat supply.	Combustion of fuel, B.T.U.	2867	4583
	Hot air	271	436
	Steam-blast	23	26
Total heat supply, B.T.U.		3161	5045
Heat capacity of gases, per lb. of fuel		1.3059	1.6058
Furnace temperature, degrees F.		.2498	.3208

If we assume the specific heat of steam to be 0.6 instead of 0.48, as assumed above, the furnace temperatures are respectively 2370 and 3100° F.

Copper melted (1980° F.) easily. Nickel melted (2640° F.) slowly.

Downtake temperature (electric pyrometer)	1388° F.	
Waste gases entering air-heater	909.0	917.0
" " leaving air-heater	610.2	680.0
Mean fall of temperature, degrees F.	298.8	236.9
Air entering air-heater, degrees F.	57.3	65.4
Air leaving air-heater, degrees F.	315.7	336.9
Mean rise of temperature, degrees F.	268.4	271.5
Wet-bulb thermometer, degrees F.	47.6	51.2
Estimated moisture in air, degrees F.	0.419	0.383

It will be noted that the feed-water supplied during test was between 1.499 and 1.555 pounds per pound of refuse burned; or, since a good American coal will evaporate some 10 pounds of water per pound of coal, under good arrangements of boiler, etc., that the refuse is equivalent in fuel value to about 15% of its weight of coal.

But as some of the steam was used for forced draft (see Balance Sheet of Heat Expenditure), the actual comparative value of the refuse as fuel was about 13½% that of coal.

Again, referring to the calculated composition of the refuse, we find that the carbon burnt was 21.33% to 31.58% of the

BALANCE SHEET OF HEAT EXPENDITURE.

	Tuesday.				Wednesday.			
	B. T. U.	B. T. U.	Per Cent.	Per Cent.	B. T. U.	B. T. U.	Per Cent.	Per Cent.
Steam (useful)......	...	1479	.....	42.57	....	1593	.....	29.45
Steam-blast.........	190	....	5.53	......	220	....	4.07	
Less heating to 358° F	23	....	.67	......	26	....	.48	
	167		4.86		194		3.59	
Warming waste products incl. steam and moisture from atmospheric temp.	722	....	20.73	......	985	....	18.19	
Heat carried up chimney.............	889	889	25.59	25.59	1179	1179	21.78	21.78
Heat in ashes.......	172	....	5.00	......	147	....	2.72	
Unconsumed carbon.	606	....	17.40	......	828	....	15.30	
Lost with ashes.....	778	778	22.41	22.41	975	975	18.02	18.02
Radiation and losses unaccounted for...	...	327	.....	9.43	....	1644	.....	30.75
Calorific Value of Fuel	...	3473	.....	100.00	...	5411	.....	100.00

original total weight; while the waste (chimney) products were 495.6% to 624%. The ratio of these percentages is 4.3% to 5%. This and other data in the table (the oxygen in the chimney gases) show that the burning has been accomplished with fair economy in the amount of air introduced into the furnace, though the economy is not as good as where good coal only is burned.

The presence of 37.5% of carbon, 31.5% of mineral matter, and only 30.5% of moisture shows that the material consisted very largely of ashes and cinders, wet by absorbing water from garbage dumped into the ash-cans. Assuming that the water all originated from this source and that it comprised 80% of the garbage (for this includes water in chemical combination, as

well as free), the garbage would have been 38% of the total, and the carbon in the cinders some 30% of the total weight.

The percentage of carbon in the ash-heaps (garbage being eliminated) must have been in the neighborhood of 50%. Since the ashes were exposed to the weather, however, it seems probable that the proportion of garbage was much less, and that the moisture was due to rainwater absorbed.

Normally, the weight of garbage in England is less than 20% of the weight of ashes produced by a given community. Therefore this set of tests represents not how much power can be derived from garbage, but how much power can be recovered from reburning ashes, if they are allowed to be contaminated by garbage by employing a single-collection system.

The following record of a test on a destructor built by Manlove, Alliot & Company, Ltd., is taken from Mr. Goodrich's book. The names of the parties conducting the test are not given. Babcock and Wilcox boilers were used.

EVAPORATIVE TESTS AT SHOREDITCH DESTRUCTOR AND ELECTRICITY WORKS.

Test No. I.—Duration, 5 hours, 8 A.M. to 1 P.M., January 10, 1899.

Total water evaporated from and at 212° F.	72,220 lbs.
Total refuse burned	75,092 lbs.
Refuse burned per hour	15,018.4 lbs.
Refuse burned per cell per hour	1,501 lbs. (13 cwts., 1 qt., 17 lbs.)
Number of cells in use	10
Number of boilers in use	5
Water evaporated per hour	14,445 lbs.
Water evaporated per boiler per hour	2,889 lbs.
I.H.P. per boiler per hour, taking 20 lbs. steam per I.H.P. per hour	144 I.H.P
Water evaporated per lb. of refuse burned from and at 212° F.	.96 lbs.

Test No. II.—Duration, 5 hours, 3 P.M. to 8 P.M.

Total water evaporated	108,319 lbs.
Water evaporated per hour	21,663.8 lbs.
Number of cells in use	10

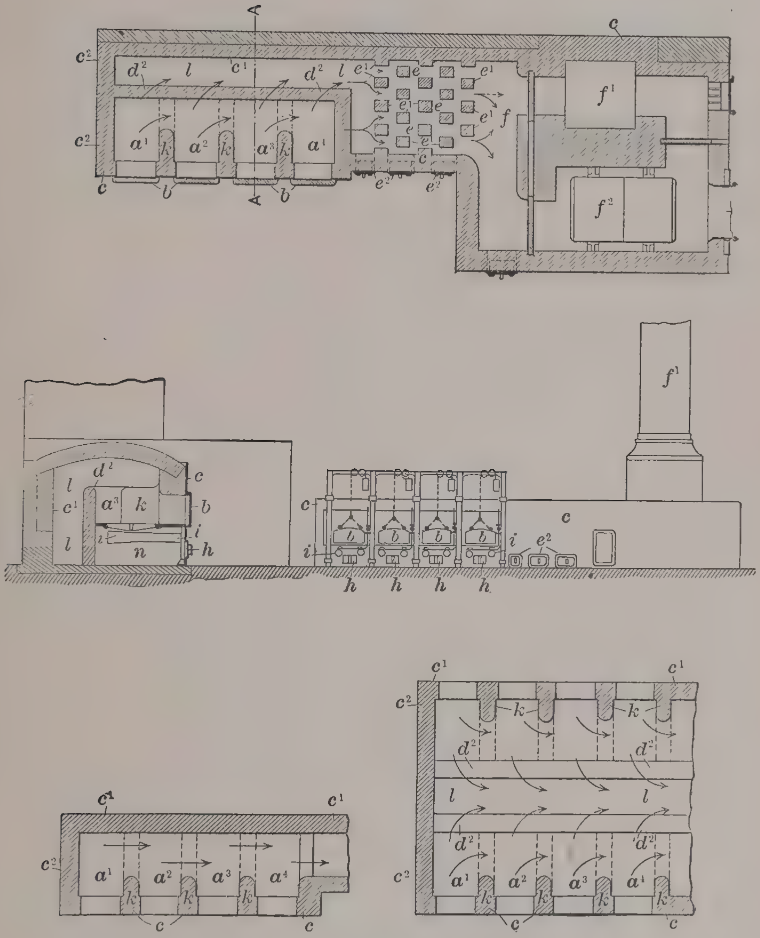

FIG. 43.—Meldrum Furnace.

REFUSE DISPOSAL IN LONDON SANITARY DISTRICTS.

Total refuse burned	60,700 lbs.
Refuse burned per hour	12,140 lbs.
Refuse burned per cell per hour	1,214 lbs. (10 cwts., 3 qts., 10 lbs.)
Total Welsh coal used (Powell Duffryn)	6,272 lbs.
Number of boilers in use	5
Coal fired per hour	1254.4 lbs.
Coal fired per boiler per hour	250.9 lbs.

ANALYSIS OF REFUSE PER YEAR ENDING JUNE, 1898.

	Tons.	Cwts.	Qts.	Lbs.
Domestic refuse	23,137	5	0	0
Trade refuse, straw, paper, tan, market refuse, etc.	2,257	9	2	14
Wood-chips about	10	0	0	0
	25,404	14	2	14

ANALYSIS OF COSTS OF REFUSE DESTRUCTION, YEAR ENDING JUNE 30, 1898.

Total quantity of refuse destroyed	25,404 tons.
Coal per ton for actual burning, including 4 furnace men, 3 top men, and 1 foreman	15.98
Ditto supervision and clerical staff	2.50
Cleaners and yardmen	6.23
Repairs	0.45
Stores, etc.	1.23
	24.39

YEAR ENDING MARCH 25, 1899.

Total amount of refuse destroyed	26,201 tons.
Cost of burning	110.20
Cost of supervision, etc.	1.86
Cost of cleaners and yardmen	3.27
Cost of repairs	1.50
Cost of stores and sundries	2.07
	26.90

1½ d. per ton burned for repairs gives a total of £163 15s. 1½d. for the year.

DISPOSAL OF TOWNS' REFUSE.

Electric energy absorbed in one year in the burning and handling of refuse.

	Units per Ton.
Electric fans.	4.0
Electric fans, total units used.	84,804 B.T.U.
Electric lifts and tipping-trucks.	0.5
Total units used by destructor.	031,348 B.T.U.
Total energy metered out to consumers, including 131,140 B.T.U. supplied to refuse-destructor.	1,031,348
Coal consumed value £1308 14s. 8d.	1,344 tons
Refuse burned.	26,201 tons.

It is of considerable interest to look into comparative figures of refuse and coal used during the year ending March 25, 1899.

Firstly, 1344 tons equal 3,010,560 lbs. of Welsh coal; this should, under good conditions, evaporate 10 lbs. of water per lb. of fuel, equal 30,105,600 lbs. of water evaporated.

Secondly, if we take the refuse consumed during the same period 58,690,240 lbs., and if, for the purpose of argument, we allow an evaporation of 1 lb. of water per lb. of refuse, we have the following very significant comparative figures.

	Pounds of Water Evaporated.
26,201 tons of refuse equal.	58,690,240
1,344 tons of Welsh coal.	30,105,600

Thus one year's coal consumption, burned under good conditions, would give more than half as much steam as a year's supply of refuse, even assuming an average evaporation of 1 lb. of water per lb. of refuse.

The question is, does it pay? Undoubtedly, where the collection system is established and cannot be changed, it should be undertaken. Where there is liberty of choice, the problem must be solved according to the special conditions of the case. This American method of applying separate treatment to various wastes, involving separate collection, does not in the slightest detract from the credit due to British engineers for solving sanitary problems under the conditions obtaining in Great Britain; but it shows the unfairness of criticism by British authorities of the American method of separate treatment, and the untruth of the oft-repeated statement that American meth-

ods of disposal are less economical than British, because we have many garbage crematories that make no effort to generate steam.

If cinders constitute 50% of ash-bin refuse, and if the refuse leaves 30% of its original weight in ashes and clinker after incineration, and refuse produces as much steam as 10% of its weight of coal, at 15 cents per ton to stoke, we have the following:

Cost to stoke 10 tons of refuse	$1.50
Expense of removing 3 tons of ash	$1.50 to $4.50
Cost of stoking and removal	$3.00 to $6.00

for each 10 tons of ashes reburned.

This will usually be found to exceed the cost of one ton of coal and stoking in America; and it must be remembered that the objections due to the steam-power not being under the same control as where coal is being burned, and that of the equipment being more costly than for coal, have still to be considered. For these reasons it seems unlikely that American cities will reburn ash-bin refuse, except in those cases where the disposal of the resulting ash can be accomplished at small expense. In the smaller cities it is not believed that the system will be found profitable, except in very rare instances.

While in America the reburning of cinders is not commonly practiced, the burning of refuse for power purposes is becoming more general, several large plants having been in operation for this purpose for some time. Usually the burning is preceded by sorting, the more valuable components of the refuse being picked out and laid aside for sale; but in some cases refuse-destructors have been installed to burn unsorted wastes,

and to develop steam for power or heating purposes; and such furnaces will undoubtedly become more numerous in future.

One of the best known of these sorting and incinerating plants is at Boston, Mass. It was built in 1898 by the City Refuse Utilization Company, which has a contract with the city of Boston, by which it receives $5500 per year plus the material sorted at the plant, which is sold. The station was designed by Col. Morse and Mr. Boulger, with the assistance of Mr. H. D. Hooker, architect. The steam raised is used only in operating the machinery employed in sorting the waste and in feeding it to the furnace. The furnace proper is of the Morse-Boulger type, elsewhere described.

The refuse-sorting and destructor station built at 47th Street and the Hudson River, New York, is another instance of a plant where sorting is done, accompanied by incineration of the worthless residue with the reproduction of power. In this case some power is available for electric lighting after that necessary to run the plant itself has been supplied. This station was designed by Mr. H. de B. Parsons of New York.

As has been stated elsewhere in this work, when garbage or refuse is properly burned, cremated, or incinerated,—whatever term is employed to describe the process,—the gases leaving the furnace should never be lower in temperature than 1200° F., and they may rise to 2000° F., or even 3000° F. If the material has not sufficient available fuel to produce these temperatures in burning, enough other fuel must be added to produce them; otherwise an offensive odor will be emitted from the furnace. The amount of fuel so required does not depend at all upon whether a boiler is installed between the crematory and the stack; consequently, in a crematory properly constructed and operated there is always heat available for raising steam. The

FIG. 44.—Exterior of Refuse-sorting and Cremating Plant at Buffalo, N. Y. (Morse-Boulger System.)

question to be solved, then, is this: Is there a sufficient market readily available for the steam so generated, when the circumstances under which it is generated are taken into account?

A destructor's primary duty is to consume the refuse promptly. This means that the firing must be done, not with a view to raising steam when steam is most needed and banking fires at other times, but with the purpose of consuming the refuse as rapidly as it is brought to the furnace. This is especially true wherever the refuse is very low in fuel value. Consequently, a refuse-destructor is capable of producing steam at hours when steam is not most wanted, and often fails to produce adequate amounts during rush hours. Obviously this is a very serious handicap, which can only be overcome in two ways:

(*a*) By employing an auxiliary steam-boiler fired by coal to make up the deficiency when the demand is excessive, and wasting the surplus steam when the demand is light; and

(*b*) By employing some storage device for power generated, such as storage-batteries in the electrical-distribution system employed for useful power.

Both of these methods involve the installation of a much more expensive plant than is necessary where a high-grade fuel is burned; and, in consequence, the utilization of heat from a refuse-furnace will be advisable or not, according to whether the price of coal or other fuel is high or low, and whether money for such investment is easy or difficult to secure.

In general, however, the installation of a boiler plant with a crematory will usually pay if there is a real use for the power available, especially in those installations where skilled attendance must be had, whether a boiler be used in connection with the crematory or not.

A word should be added regarding the advisability of reburning ashes from house collections in large cities under some cir-

cumstances, even when the power developed may not be worth the cost of stoking. If the destructor is located so as to make the haul to it very much less than to the nearest point where ashes can be disposed of by filling, it will be profitable to reduce the quantity to be hauled by burning all that is collected and hauling away the ashes only—that is, reducing the weight of ashes to be hauled the long distance to about one-third of the total quantity collected.

For example, assume that in a given district the collection of ashes costs, on an average, $1.00 a ton, and the hauling it to a distant dumping-ground, where it is disposed of without profit, $1.50 per ton, making the total cost for collecting and disposal $2.50 per ton. If a destructor can be installed at some place near or in the collection district to which the haul will be 50 cents per ton, if the operation of the destructor costs, including interest and depreciation, 25 cents per ton, and if the hauling of the ashes not consumed by the destructor to the dumping-ground costs $1.50 per ton, the total cost of disposal with the use of the incinerator will be, per ton, as follows:

Collection	$1.00
Haul to destructor	.50
Incineration	.25
Haul from incinerator, $\frac{1}{3}$ ton	.50
Total	$2.25

From which it appears that incineration would be cheaper, and that any power available for other purposes would be a clear profit. With coal at $4.00 per ton, and ash-bin refuse capable of producing 10% as much steam as the same weight of coal, the fuel value per ton of refuse is 40 cents, and the saving by installing the destructor would be, in this case, 65 cents per ton.

It should be remarked, however, that the incinerating plant is seldom located, or seldom can be located, so as to effect such saving in haul; and that usually the haul to the incinerator is practically equal to the haul to the dump, the haul from the incinerator to the dump being an added expense.

CHAPTER VIII.

MATERIALS AND METHODS OF CONSTRUCTION.

All materials of construction are liable to expansion when subjected to heat, and, with the range in temperature employed in a crematory, expansion is a very important matter, as it may cause weakening of the furnace, unless provision is made to prevent that.

High-grade fire-brick should have a very low coefficient of expansion. The expansion of chimney linings is stated by H. N. Brickerhoff (*Eng. Rec.*, Vol. 29, p. 400) to be from 0 to 2 or 3 inches in 75 feet height. As a rule, the harder burned the brick the less its coefficient of expansion. The coefficient of expansion of ordinary brick is about .000,005. The coefficient of expansion of common cast iron is .000,0062. This would make an expansion of about one-third inch in a grate-bar 5 feet long, heated from ordinary temperature to a red heat. Steel has about the same coefficient of expansion, and concrete practically the same at ordinary temperatures. This is one reason why properly reinforced concrete does not ordinarily crack, or the steel loosen from the concrete by longitudinal expansion.

If a fire-brick lining is bonded into a common brick outer wall, the expansion of the lining subject to intense heat should not be any greater than that of the wall, or it will cause the wall to crack. It is practically impossible to prevent common brick walls from being cracked by the expansion of the fire-brick lining in a long furnace, if the lining is laid with tight joints

and bonded into the outer wall. This is a serious fault of most brick furnaces.

An air-space may be provided between the fire-brick lining and the wall of common brick, or of reinforced concrete, to allow freedom of expansion. This involves the making of the fire-brick lining practically self-supporting

When the crematory consists of an iron shell with a fire-brick lining in contact with the iron, the iron, though moderately heated, may expand at the same rate as the brick, which is intensely heated on its inner surface, so that no space for expansion may be necessary.

The fire-brick lining of a crematory is relied on to keep the heat from escaping from the furnace. It should be thick enough to accomplish this—in a municipal plant nowhere less than 9 inches, which is the length of a common fire-brick. The brick should have as small a coefficient of expansion, as small heat conductivity, and as much mechanical strength and toughness as possible; and it should be able to stand 2500° F. to 3000° F. without incipient fusion. Much fire-brick fuses at a lower temperature than this, and usually bricks that will stand very high temperature are not strong enough to stand the mechanical wear to which they may be subjected in a crematory. Special blocks should be made for feed-hole linings, door arches, and all places where peculiar forms are necessary. Special care should be taken in laying the brick, to see that joints are entirely filled with fire-clay, but that they are as thin as is possible to make them. Fire-clay joints invariably shrink after laying; and the bricks should be laid as close as if no clay were used, only the interstices, which would otherwise be open, being filled with clay, so that, although the clay shrinks, the wall will not.

Two crematories of the same design, but of different sizes,

may be assumed to have capacities for destroying refuse proportional to their respective sizes; but the part to be used as a basis for comparing sizes is different in different designs. For example, in furnaces of Class 2 we may take the area of burning-grate as the criterion, and dispose of 30, 40, 50, or 60 pounds of garbage per square foot of grate area (the precise figures depending upon the particular design, the draft, etc.); the stronger the draft, the greater the capacity per square foot; or in furnaces of Class 3 we may make the area of the garbage floors the criterion, and dispose of so many pounds of garbage per square foot of floor-space: but the capacity of square foot depends upon the temperature applied. Thus we see that relative size is only a fair criterion for furnaces operating at the same temperature and in the same way. A very large furnace, a considerable portion of which is not very hot, would not dispose of as much garbage as a small furnace in which there is an intense heat; and, in burning refuse, an intense heat would be useless unless there were also a considerable volume of air admitted in the proper places.

The size of the combustion-chamber, or chambers, must be large enough to complete the combustion thoroughly before the gases pass to the outer flue, both to prevent odors and to secure uniform temperature of the chimney gases.

In Goodrich's book on refuse cremation, considerable space is given to a discussion of the quantity of refuse destroyed per square foot of grate area. The discussion there given should be understood to apply only to furnaces of Class 2.

The problem of drying garbage upon a platform or set of grates in a crematory is very similar to the problem of evaporating water in a steam-boiler, though the difficulties in securing an efficient mechanical construction in a crematory are greater than in a boiler.

In a boiler we aim to secure, primarily:

(1) As much surface of boiler-tube exposed to the hot gases of combustion in as small a space as possible.

(2) Perfect circulation of the water in the tubes, so that all the surface exposed to the heat will be effective.

We have to contend against:

(3) The slow flow of heat through the metal of the boiler-tubes, and any deposit of scale inside of the tubes or of soot upon their surfaces.

We may contrast these conditions as follows:

(1) *In a crematory* we aim to secure a large surface of garbage exposed to hot gases of combustion in as small a space as possible. But this is difficult, especially with kitchen garbage, or "swill," night-soil, sweepings containing dust, wet straw, manure, and like wastes, that cannot be suspended, so that fire will pass through the mass, as between boiler-tubes. Such material can be exposed to direct heat passing *over it*, and partially, on a divided hearth, to direct heat *beneath it*, as in the Dixon and Boulger furnaces illustrated; or it may have direct heat above and indirect heat below, as in some of the Smith patents: but, in any case, the volume of the chambers in which the drying is done must be much greater than is necessary to evaporate an equal weight of pure water in a modern boiler, where the tubes are arranged for the gases to pass through or between them.

(2) *In a crematory* it is manifestly impracticable to circulate the garbage, as water is circulated in boilers, so as to always expose the wet surfaces to the action of the fires. In some furnaces this is not attempted, the garbage being roasted and burned on the same hearth with little or no stirring. See Walker and Dixon patents. The Boulger furnace and McKay's furnace are designed for stoking from one hearth to another.

(3) *In a crematory* the interior of a mass of garbage may be in a semi-fluid condition when the exterior is incandescent from applied heat, the surface forming a crust or a bed of ashes protecting the material within. To obviate this is difficult, especially where the material being incinerated produces a large amount of ash, as does manure or straw.

We see, then, that it is not possible to evaporate water from garbage with the same efficiency as in a boiler, because (*a*) the furnace must be much larger, and the loss by the radiation greater, and because (*b*) the process of stoking and burning the garbage admits an excessive amount of air into the furnace, even when the utmost practicable precautions have been taken.

We have hitherto classified crematories according to the principles dominating their respective designs. There are, however, two *types of construction* in use by most builders,—the *iron-clad* types and the *masonry* types.

The iron-clad type consists of a shell of cast-iron or of steel, from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch thick, that is sufficiently rigid to hold the lining in place, and an interior lining of fire-brick in which are mounted the grates and other accessories. This type requires less floor-space than the masonry type. It can be built entirely in a factory, requiring comparatively little construction work at erection. Usually it is provided with a receiving-pan for garbage, placed above, into which carts may be dumped, but over which they may not drive.

The masonry type consists of a furnace of fire-brick surrounded by walls of common brick or concrete, which support a floor above, upon which carts and wagons may drive. It is more expensive than the iron-clad type, and requires more space. The fire-brick furnace walls should not bear any of the weight of the driveway above, nor should the outer walls receive any thrust due to expansion of any of the fire-brick lining or grates.

Disposal of Liquids.

Where garbage is brought to a crematory, saturated with liquid, the liquid may be drained off,—

(*a*) before the garbage is placed in the crematory;

(*b*) in a special compartment in the crematory; or,

(*c*) in the crematory where the drying is done. In any case, the free liquid must be disposed of.

If the crematory is in a city provided with a system of sewers, the liquid may be drained into the sewer, provided there is no especial objection to this. If the sewer is connected to a sewage-purification works, the garbage drain should not be connected to it without a preliminary determination that such connection will not be injurious to the works in question.

If, however, the liquid is to be evaporated in the crematory, precaution must be taken in the design to see,—

(*a*) that it will all be evaporated without emitting offensive odors;

(*b*) that it will not be injurious to the material of which the furnace is built.

Preliminary draining before placing in a furnace is often resorted to, when the liquid is to be evaporated, as well as when not, the liquid being conveyed to a specially constructed evaporating-chamber; but such draining does not make the garbage so dry that it will not drip when placed in the furnace. Some of the water almost always finds its way to the ash-pits, and must be evaporated there, or drained thence; and, if the arrangement is such that liquid gets into ash-pits already containing ashes, it makes the ashes so foul that they are unfit for removal. This is a serious defect in many furnaces, and not

unfrequently occurs even with furnaces of good design when improperly operated.

The location of the evaporating-chamber for liquids is of importance. In furnaces such as illustrated, where the garbage is reduced on a single hearth, no additional chamber is provided. In the Dixon furnace the ash-pit serves the purpose, garbage being placed in the furnace when there is no ash in the pit, and the liquid being evaporated before ash is produced from the garbage, the ashes being withdrawn before the cell is again charged with swill. All gases from the ash-pit must pass over the fires. In the Boulger furnace the evaporation is done in the ash-pit, but between the stench-fires and the stack. The smell, however, is effectively destroyed. Other arrangements are shown in the drawings, while some furnaces have no means of evaporating these liquids at all.

The size and the number of feed-holes are another matter regarding which practice differs, some builders providing feed-holes large enough to dump a cart-load into, and others preferring smaller openings, and the feeding of the material into them more deliberately. The smaller openings leave the furnace stronger, and preserve the grates from receiving too heavy shocks from dumping large weights upon them. The labor involved in dumping into a hole 2 feet in diameter is only a very little greater than in dumping into one 4 feet in diameter.

The following are the chief causes of failure of crematories that have failed completely:

1. Faulty design, resulting from ignorance of the natural general laws governing the proportioning of the various parts of any furnace, such as the relation of the size of chimney to the size of grate, to the air admitted, and to the draft; the drying area required; the temperature of com-

bustion; the cause of odors, etc. This is the cause of most failures.

2. The use of cast-iron where subjected to temperatures higher than the cast-iron will bear.

3. Failure to allow for expansion of heated parts, causing furnaces to crack.

4. The use of fire-brick linings bonded in common brick, or of fire-brick linings too thin to be stable.

5. The use of inferior fire-brick, or other materials of poor quality.

6. The installation of a furnace, adapted to burn refuse only, to burn garbage only, for which it is not adapted.

7. Unskilled handling by ignorant operators.

It should, in justice to the builders of municipal plants, be added that the fault for most failures lies at the door of the municipal authorities, on one or other of the following scores:

(*a*) Acceptance of an untried installation designed by some local party without substantial experience or attainments in the line of this work.

(*b*) Contracting, in good faith, for an unsuitable installation, because of ignorance, by the purchaser, of what the conditions to be met really are.

(*c*) Determination by the municipal authorities to award work to contractors who will pay the largest sum to those who have the power to determine who shall secure the contract.

Unfortunately, in spite of the recent outcry against graft, the affairs of most American cities and towns are controlled by persons who either demand such contributions from public contractors for themselves, or permit their subordinates to demand them, in order to retain the service of those subordinates. So many, so various, and so subtle are the methods by which political prostitutes may cheat the people of money, that

few contractors, and few engineers, are able to withstand the pressure brought to bear upon them, if they seek to serve a public where the grafters are in control, or even in the minority, on the city council, or other public body in control of municipal administration.

FIG. 45.—Crematory Building at Fort Riley, Kans.
(Sanitary Engineering Company.)

CHAPTER IX.

CREMATORY CHIMNEYS.

The proper size and best design for a chimney for any specific service, even in steam-power production, are matters upon which opinions widely differ. The best and most available work on the subject is Christie's *Chimney Design*, in which reference is given to numerous other authorities. This book, however, does not much discuss reinforced-concrete chimneys, which are now coming into extensive use.

The service demanded of a chimney for a crematory depends entirely upon what is to be burned, refuse requiring a chimney of much larger section than garbage, as the following illustrations will show:

Assume a crematory using 200 pounds of soft coal to burn 1 ton (2000 pounds) of kitchen garbage, which is 80% water and 20% combustible, equal to half its weight of coal. We then have to consume the equivalent of 400 pounds of coal, and to evaporate 1600 pounds of water. Each pound of coal requires about 20 pounds of air for proper burning. The weight of chimney gases will then be $1600+(400\times21)=10,000$ pounds. The weight of gases from burning the 200 pounds of coal only would be 4200 pounds, so that this crematory requires a stack of $\frac{10,000}{4200}=2.4$, the capacity required to burn the coal alone. Or, we may say, in burning one ton of coal 42,000 pounds of gases are produced. Then burning garbage in this

crematory requires a stack of $\frac{10,000}{42,000} = .24$, the capacity necessary to burn an equal weight of coal, or, approximately, a stack large enough to burn coal equal to $\frac{1}{4}$ the weight of garbage to be burned.

On the other hand, if the refuse is highly combustible, requiring no auxiliary coal, and equal in heat-value to $\frac{1}{2}$ its weight in coal, the stack required would have to be large enough to burn coal equal to $\frac{1}{2}$ the weight of garbage to be burned.

A crematory for mixed garbage and refuse, capable of burning either, requires a stack intermediate in size. For general service it will be safe to design the stack of the size necessary to burn as much soft coal per hour as is equal to one-third of the garbage to be burned each hour. This rule and the table opposite will enable prospective buyers of crematories to determine whether or not a certain stack is likely to prove adequate for the work. It is not put forward here as of extreme accuracy. The table is an adaptation from data contained in Christie's book, page 25.

The following are the principal varieties of chimneys, with some comments on each:

1. *Guyed Iron Stacks.*—These are the cheapest in first cost, and therefore have been used extensively. If used with crematories, they should be lined to the top with fire-brick. Otherwise they should not be expected to last a year at the temperature employed. They may last three years or more if lined, and if in a climate where they do not easily corrode. The guy-lines require plenty of space.

2. *Self-supporting Steel Stacks.*—These are free from the objection of requiring excessive space, but are not usually cheaper than masonry stacks. An iron stack expands and contracts more than a masonry stack of the same internal

Chimney Tables for Crematories.

Diameter, Inches.	Height of Chimney, Feet.								
	50	60	70	80	90	100	125	150	200
	Tons Kitchen Garbage per Hour.								
18	0.33								
21	....	0.5							
24	....	...	...	0.75					
27	0.75		...	....	1				
30	....	1							
33	....	...	...	....	...	1.5			
36	....	...	1.5	....	...	...	2		
42	....	...	2	....	...	...	...	3	
48	....	...	...	....	3	...	...	4	
60	....	...	...	....	...	5	...	6	
72	....	...	...	....	....	...	...	...	10
	Tons Dry Refuse Only.								
21		.25							
27	....	...	....	....	.5				
30									
36	....	...	0.75	....	...	...	1		
48	....	...	....	....	1.5	...	...	2	
60	....	...	....	....	...	2.5	...	3	
72	....	...	....	....	...	...	4	...	5
	Tons Mixed Garbage and Refuse.								
18	0.25								
24	....	....	0.5						
30	....	0.75	....	....	...	...	1		
36	....	....	....	...	...	...	1.5		
42	....	....	1.5						
48	....	....	....	....	...	...	...	3	
60	....	....	....	....	...	4	...	...	5
72	....	....	....	....	...	...	6		

diameter, and bends more. For crematory work it should be lined to the top with brick, and the expansion renders the lining less permanent than in masonry stacks, especially in high chimneys of small diameter.

3. *Solid-brick Chimneys.*—These are the heaviest and most expensive to build. They depend upon their weight for stability

at every height. Where chimneys are not very high, the expense is not prohibitive. The design may be very ornamental.

4. *Radial-brick Chimneys.*—These are built of hollow brick, and are cheaper and stronger than the solid-brick chimneys, and perhaps the least subject to vibration of all chimneys.

5. *Reinforced-concrete Chimneys.*—These are the strongest chimneys built. In price they are close competitors of the radial brick. Their columns have much thinner shells. For crematory work, they should be lined for at least half their height. They vibrate slightly in the wind,—much less than the self-supporting steel columns, but more than radial brick of the same inside diameter.

Height.

Garbage contains considerable sulphur, besides small quantities of all the common elements. When burned perfectly, the gases given off are somewhat more pungent than the smoke from soft coal; but there need be no soot. The odors from the chimney of a properly operated crematory are about as objectionable as those from a properly operated steam-power plant. The height of a crematory chimney should therefore be 25 feet or more than the roof of any neighboring building; but if the gases drift down to earth at a distance, they should not prove objectionable.

Very tall chimneys should always be provided with lightning-rods.

It frequently happens that it is desired to connect small crematories or refuse-burners to flues already constructed,—often to chimneys in which a number of other furnaces also discharge. Great care should be taken in such cases to make sure that the flue and the stack are large enough for the service.

This can only be ascertained positively by an examination of each case. Such flues should be lined with fire-brick.

There are several patents covering certain methods of chimney construction, and several covering methods of supporting fire-brick linings, but there is nothing covering any of the general classes of chimneys named so fully as to exclude competition.

Great care must be exercised to secure a suitable foundation for a self-supporting stack, as well as to make the column proper sufficiently strong to resist wind-pressure.

CHAPTER X.

SUMMARY AND SUGGESTIONS.

THE engineer or superintendent having some particular problem of waste-disposal to solve often finds need of a ready guide as to the methods of disposal that are worth investigating, with reference only to his particular problem. For the benefit of such, this chapter is written. It defines the field in which each method of disposal may be properly applied, according to the views of the writer. As each promoter is usually anxious to extend the field of his own apparatus, it is not to be expected that the advocates of the various systems in use will acquiesce completely in the limitations of their fields herein suggested. However, these suggestions will be found to cover most cases fairly and liberally.

1. *Institutions, hotels, apartment houses*, etc., where the buildings are not widely scattered, having to dispose of wastes of 15,000 *persons or fewer*, will not find it economical to install reduction-plants or refuse-sorting systems of any kind, because they have only such a quantity of garbage and refuse as one man can handle in a crematory without assistance.

(*a*) If such institutions are in a large city, the garbage may be delivered to the city garbage-collectors who call each day. The rubbish can be more conveniently burned on the premises, because it is bulky, and frequently the municipal collection of such litter is so infrequent as to make the amount accumulating

between collections a nuisance. Moreover, rubbish can be burned advantageously to raise steam for power purposes; and there is invariably a need for steam or hot water in such institutions.

(*b*) Institutions of this size, so situated that the garbage must be disposed of on the premises, will find it advantageous to burn both garbage and rubbish in the same furnace, though separate collection is preferable.

Crematories for such institutions should be located in the power-house, if there is one, and provided with connections by which the hot gases may be used for steam-raising. A separate boiler for the crematory is preferable if the operation is sufficiently continuous. Wherever the crematory is operated only a few hours a day, or a few days a week, it is better to connect it with a boiler that can be separately fired when the crematory is idle. If there is no power-house, it should be located in the basement of the largest building.

A man can stoke about one ton of mixed garbage and refuse per hour. Therefore it is most economical to install a crematory of that capacity, or larger, and to operate it at full capacity for such time as may be necessary, unless the quantity of waste to be destroyed is very small.

2. *Institutions and villages of from 10,000 to 40,000 persons* will find reduction and sorting unprofitable, because the quantities handled are too small. Such communities should burn the garbage and the refuse, the problem to be solved being the advisability of attempting to utilize the heat generated by the burning.

(*a*) If the corporation undertaking to operate the destructor has a steam-power plant, in connection with which the destructor may be built, the utilization of the heat for steam-raising will almost always pay, provided that, by locating the destructor at the power-plant, the distance that the wastes must be hauled is not unduly increased.

(*b*) If the corporation that will operate the destructor has no steam-power plant, it will usually not be advisable to build one especially for use with the destructor, but will be preferable to make no attempt at economy of this kind.

Crematories having to dispose of the wastes of 20,000 people or more should preferably operate continuously, day and night. This gives them higher efficiency and less first cost and depreciation per ton destroyed.

3. *Municipalities of over 40,000 population* are justified in considering propositions of sorting wastes and "reducing" garbage, in connection with a crematory plant for destroying the solid residues, and a sewage-disposal system for disposing of the liquids pressed from the garbage; but there will be found only a limited number of places where such utilizations will be profitable.

(*a*) The proper sorting of refuse requires that the material be fed upon an endless belt, and that a sufficient number of persons be employed to stand by the belt and to pick out the marketable articles of various kinds, classifying them in bins as they are removed. There must be enough refuse to keep a number of persons busy at the sorting, as each picker can handle only a few kinds of wastes, and there are many kinds,—half a dozen grades of paper, woolen, cotton and linen rags, bottles, bones, cans, various metals, leather, etc., the value of which depends largely upon the care with which the sorting is done. Refuse to be sorted must be free from garbage. The residue should be cremated. It is from 40% to 60% of the original quantity.

(*b*) The reduction process requires a high-pressure steam-chamber in which to cook the garbage with steam, presses to separate the solid material, tanks to separate the grease and oil from the liquid after pressing, and means for disposing of the

waste liquid. This latter is usually discharged into rivers or lakes, where it putrifies. Thus it is seen that steam-power and considerable machinery is necessary. Obviously, to be profitable, the quantity to be handled must be sufficient to keep a force of employees busy all of the time. Whether the process will pay, or not, depends also upon the market for the products extracted, and the efficiency with which the work is conducted. This must be carefully considered in each particular project.

(*c*) If (*a*) and (*b*) or either of them are adopted, the residue may be burned to produce steam for operating the necessary machinery. If they are not adopted, a larger quantity of steam will be available for power purposes of other kinds, such as electric-lighting, if any market therefor is available. Thus it will be seen that the utilization of wastes by converting them into salable by-products takes away from the value otherwise to be realized in some cases as fuel for steam-raising. All elements considered, it usually will be found more advantageous for small cities to burn both garbage and refuse, in connection with a power-plant, than to utilize them otherwise. This method is by far the simplest, and entails a much less cost and a much less risk, than more elaborate systems.

4. *Cities of over 200,000 inhabitants* are large enough to adopt, with profit, any system of utilization, if conditions show that such profit can be derived under the other circumstances actually existing. In the larger cities it will be found that separate and distinct plants may be employed to advantage to dispose of the different classes of wastes. The choice may be made among the following systems, or by combinations of those systems:

(*a*) Common collection of garbage, refuse, and ashes, and burning them in a destructor, generating steam for power purposes. This is the British practice. The objection to it in

America is, that by separate collection of ashes the handling of them in the crematory is avoided; and that, under circumstances usually existing in America, the heat recovered is not worth the cost of the extra handling involved. There may be some localities where this is not so.

(*b*) Separate collection of ashes, and disposal of them for filling.

(*c*) Common collection of garbage and rubbish, and cremation of the mixture. This may be done in one central plant, with the production of steam for power, or in a number of smaller plants, located so as to reduce the length of haul in each collection district to a minimum.

(*d*) Separate collection of rubbish, in combination with sorting and burning the residue, with incidental production of power, in a centrally located plant.

(*e*) Separate collections of rubbish and garbage, and their burning together in moderate-sized crematories located near the centers of the collection districts.

(*f*) Separate collection of garbage and its "reduction," to extract the grease, in a suitably located plant.

(*g*) Separate collection of rubbish, and its burning in small incinerators located near the centers of collection districts.

The writer believes that in most American cities the combination of systems (*b*) and (*e*) will be found most advantageous from all points of view. Next in advisability appears the combination of (*b*) and (*d*) and (*f*), for the larger cities especially. Where sufficiently advantageous contracts can be made to sell garbage, f. o. b. cars, to some reduction company, the best method of disposing of the remaining waste appears to be by combining (*b*) and (*g*). System (*a*) is recommended when transportation from all parts of the city to the disposal plant can be had by rail, and the ashes from the plant sold f. o. b.

cars, and where there is an assured market for the power at remunerative rates. System (*c*) is recommended only where the common collection system is inapplicable because of inability to enforce the separate system.

If an institution or a private corporation is in the market for a crematory, it can proceed with an investigation of the various devices on the market and purchase at its own discretion; but a representative body or a public officer is usually constrained by law to advertise for bids, and to accept the "lowest," or the "lowest and best," reserving the right to reject "any or all bids." Usually, when all bids are rejected, which not unfrequently happens, the fault is with the advertisement or specifications, which do not define with sufficient clearness what is to be bid upon. The mere statement in the advertisement that the crematory "must burn 25 tons of garbage or refuse per day," or that the "cost of cremation must not exceed 50 cents per ton," are too indefinite to secure bids on anything like a uniform basis.

The advertisement should clearly set forth to whom bids are to be addressed, when they will be opened, the size of the plant, from whom specifications may be procured, the bond required with the bid, the location of the crematory site. Wherever possible, the site should be procured before bids are asked for, and it is unfair to contractors to keep the matter open until after the bids are taken.

For the convenience of those municipal authorities who are required to call for bids under specifications admitting of competition, the following suggestive specifications are given. These apply only to crematories to which boiler-plants are not to be connected, which is the case in the large majority of municipal plants.

SPECIFICATIONS FOR A GARBAGE CREMATORY.

These specifications relate to constructing a crematory, with a chimney and a suitable building, for ————, upon ground to be furnished by ————, and to provisions connected therewith.

Each bidder on the proposed work is required to enclose with his bids a surety company's bond for a sum equal to 10% of the amount bid, or a certified check for the same sum, guaranteeing that said sum will be paid ———— in case the work is awarded the bidder and he fails to enter into contract for same, and to furnish bond, as hereinafter provided, within ten days after notice of said award has been served upon him.

The bidder to whom award is made must furnish acceptable bond in a sum equal to 50% of the amount bid, guaranteeing that the contract then entered into will be faithfully performed, said bond to remain in full force until final payment has been made to the contractor as hereinafter provided. Said bond shall apply not only to the construction work set forth, but to the guarantee of the performance of the crematory made by the bidder hereinafter referred to. A copy of the specifications must accompany the bid, and bids in which the provisions of these specifications are modified shall not be considered. The bidder must also submit with his bid a complete specification of a building and the apparatus that he proposes to furnish, with plans descriptive thereof supplementary to these specifications, sufficient to fully indicate what he proposes to furnish, as to both design and quality of materials, including foundations.

In submitting a bid, the bidder guarantees that the apparatus offered by him does not infringe the patent rights of any other party, and that he will stand any losses that may be incurred by the purchaser owing to any such infringement.

The bidder must also state with his bid the features of the crematory offered by him that are patented, giving the numbers of said patents when required. He must also state what features, if any, are the subject of pending patent applications. Any bidder who fails to comply with this requirement may have his bid considered, but in bidding on this work without making such statements he shall forfeit all right to prosecute ————, or any other bidders for infringement of patents relative to the particular apparatus he offered in this particular case.

The bidder must state the date at which he will commence the work, and the date at which he will complete the same.

Upon completion of the whole of the work contemplated herein, the ———— shall have a final inspection made to determine whether it complies with the specifications and plans in so far as structure and workmanship are concerned. When the work is completed in these regards it shall be accepted, subject to test, and enter upon a test run of thirty days to demonstrate its capacity, cost of operation, and mechanical soundness. If in such tests it is found to comply with the guarantee hereinafter set forth, and those additional guarantees made by the bidder, final payment shall be made; otherwise, ———— shall be entitled to withhold from the contractor and to recover from his bondsmen an amount equal to the value of the fuel and the labor required to operate the crematory at the full capacity called for, in excess of that guaranteed by the contractor, for a period of 1500 days, upon the basis of market prices at the time tests are conducted. In case said sum so estimated exceeds the amount of the bond,———— shall reject the entire installation, and shall be entitled to recover from the contractor all sums paid therefor on account, for which the bondsmen shall also be liable to the full extent of the bond.

Payments shall be made in monthly estimates, on account, to the extent of 50% of the value of the work, according to the price bid; 25% of the contract price upon final inspection, and the remaining 25% on the termination of the 30-day test run, if the guarantees are fulfilled.

During the 30 days' test run the plant shall be operated by the purchaser, who shall furnish all labor and fuel required; but the contractor shall be represented by a competent expert who shall direct the operation, and whose instructions shall be obeyed. In case, in the opinion of said expert, any employee or employees fail to do their work properly, the expert may suspend him and procure other help. Determinations of capacity and fuel consumption shall be made only when the crematory is being operated at its full capacity for the number of hours stated in the contract.

The crematory shall be capable of burning ———— tons (of 2000 pounds) of garbage or refuse, or of garbage and refuse mixed, in a continuous run of ——— hours.

The burning must be conducted so as not to produce offensive odors either at the crematory or from the chimney. By offensive odors are meant those due to the incomplete combustion of organic matter. Completely oxidized inorganic gases shall not be considered offensive. The chimney gases must be free from smoke. The temperature of gases leaving the crematory must not be less than 1200° F. at any time.

When burning kitchen garbage only at full capacity, on a continuous run of 16 hours, the crematory, or any cell of the crematory on a test, must not require more than 200 pounds of coal or equivalent per ton of garbage consumed, said coal being equivalent in heat-producing value to 14,000 British Thermal Units per pound, and the gases leaving the crematory being not lower in temperature than 1200° F.

In case the bidder desires to offer a better guarantee of efficiency than this, his offer will be considered if stated in his bid.

The labor required to operate the crematory at full capacity shall not be more than the labor of one stoker working eight hours for each six tons of garbage or refuse consumed. This shall include all labor of charging, firing, and removing ashes from the building. In case the bidder desires to offer a better guarantee than this, his offer will be considered if stated in his bid.

The general arrangement of the crematory and building shall be as follows:

There shall be a basement or stoking floor, where the stoking is done, the fires are tended, and the ashes removed; and above this a receiving floor, reached by a driveway, and feed-holes for charging the furnaces. The walls up to the receiving floor shall be of brick or concrete.

The chimney shall be of reinforced concrete or of radial brick, lined in either case to the top with cupola brick. It shall be capable of resisting a wind pressure of 50 pounds to the square foot.

The superstructure above the receiving floor shall be of brick or stone, with steel roof-truss, slate or tile roof, wire-glass windows, and fire-proof doors.

INDEX.

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